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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 597

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 9, 1918

SOME BIOLOGICAL AND CONTROL STUDIES OF GASTROPHILUS HAEMORRHOIDALIS AND OTHER BOTS OF HORSES

By

W. E. DOVE, Scientific Assistant
Insects Affecting Domestic Animals

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SOME BIOLOGICAL AND CONTROL STUDIES OF GASTROPHILUS HAEMORRHOIDALIS AND OTHER BOTS OF HORSES.[1]

By W. E. Dove, *Scientific Assistant, Insects Affecting Domestic Animals.*

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INTRODUCTION.

In compliance with requests from farmers and horse breeders of the Dakotas and Montana regarding "fly annoyance" to horses, a survey of conditions was made in the autumn of 1914 by Mr. F. C. Bishopp. Under the direction of Dr. W. D. Hunter and the supervision of Mr. Bishopp, investigations were undertaken in the following summer upon the European *Gastrophilus haemorrhoidalis*, commonly known in that section as the "nose-fly."

The preliminary investigations in the summer of 1915 revealed the fact that the concentration of horses in pastures had rendered breeding conditions practically ideal for bot-flies, and that a most serious fly nuisance had developed which implicated three species of Gastrophilus. This concentration of horses in pastures may be attributed in part to the advent of gas engines, automobiles, and tractors, and to maximum prices, which has encouraged the breeder

[1] Mr. H. B. Bradford made the drawing illustrating the eggs of Gastrophilus, and Mr. W. N. Dovener made those illustrating the larvæ and dorsal aspects of the adults. Many of the photographs were made by Mr. A. K. Pettit.

to meet the great demand for army horses. Within the nose-fly district is to be found one of the largest horse-sale points in the world.

BRIEF LIFE HISTORY OF GASTROPHILUS.

Our knowledge of the life histories and habits of these insect pests, which is always essential to successful control, is confined for the most part to the classical accounts of Bracy Clark in 1797 and subsequently, although later writers have added important details.

When the female of *Gastrophilus intestinalis* (*G. equi*) becomes sexually mature it is most often observed hovering near the inside of the knee of a horse, where by preference the eggs are deposited. After a few days, when the larvæ develop within the eggs, the horse by scratching the forelegs with the teeth provides sufficient moisture and friction to remove the operculum or small cap of the eggs and inadvertently the larvæ are taken within the mouth. The empty eggshells remain attached to the hairs of the legs, whereas the larvæ are carried with the food or water to the stomach, where attachment to the stomach walls takes place. Here they undergo development during the autumn, winter, and spring months, and later are passed from the horse with the manure. At this stage pupation ensues and adult flies are produced.

The other species of bots also spend similar larval periods in the animal, but have habits peculiar to the particular species.

HISTORICAL.

The literature containing historical references to the Oestridae carries one to a most remote time. The ancient Greeks and the Latins refer to "an unspeakable fright of cattle," though later writers are not agreed as to whether it was produced by an oestrid or a tabanid. It is certain, however, that Aristotle knew the forms found in the throats of deer.

The Greek veterinarians Theomnestus and Absyrtus give us the earliest record which could be referred to Gastrophilus when they write of the "biting worms which fix themselves to the anus of the horse." In order to destroy them it was recommended that they be torn from the anus with the fingers and covered with hot ashes and pulverized salt.

Malpighi in 1697 gave the first description of a gastrophilid larva taken from the stomach of an ass. According to Joly, it belonged to the species *G. intestinalis* De Geer, while to Brauer it was *G. flavipes* Olivier. Gaspari published an erroneous opinion that *G. haemorrhoidalis* deposited its eggs in the rectum of the horse during defecation, and that the larvæ migrated to the stomach until about fully developed. Vallisnieri and Réaumur made the same erroneous diagnosis.

Linnaeus, Fabricius, and De Geer occupied themselves with the early classification, and not until 1797, with Bracy Clark, does the natural history of the Oestridæ truly commence. To this historical work of Bracy Clark a few additions, many of which are cited in the bibliography, have been made by subsequent writers.

In conformity with the rules of nomenclature and following the reestablishment of the Linnaean designation "*intestinalis*" by Guyot, "*Gastrophilus intestinalis*" is given preference rather than "*Gastrophilus equi.*"

Aside from priority, the specific name "*equi*" is not reliable, since there are several species of Gastrophilus which infest the horse; moreover "*intestinalis*" has been adopted by a number of dependable authorities.

FIG. 1.—*Gastrophilus nasalis:* Female. Oviposits commonly under the jaws of horses. Greatly enlarged. (Original.)

SPECIES DIFFERENTIATION.

The eggs, larvæ, and adults are so easily distinguishable in this genus that it does not require a study of detailed descriptions to enable a student to determine the species. (Figs. 1, 2, 3.) Prof. Garman's key to the wing venation, a reliable index to the species, is here quoted.

KEY TO WING VENATION OF GASTROPHILUS SPP.

1. Discoidal cell not closed by a cross vein ..... *G. pecorum.*
   Discoidal cell closed by a cross vein 2
2. Wings marked with brown ..... *G. intestinalis.*
   Wings not marked with brown 3
3. Anterior basal cell nearly or quite equal to the discoidal cell in length ..... *G. nasalis.*
   Anterior basal cell markedly shorter than the discoidal cell ..... *G. haemorrhoidalis.*

The cloudy wings of *G. intestinalis* and its habit of depositing upon any convenient portion of the horse where it is not disturbed, but most commonly on the forelegs, will enable one to distinguish it most readily.

G. nasalis is smaller than *G. intestinalis*, densely hairy, with the thorax yellowish red or rust colored. Its most common place of oviposition is under the jaws, but it is sometimes observed to oviposit

upon the flanks or forelegs of the animal. Unlike *G. intestinalis*, it does not remain near the animal prior to the deposition of a second egg.

G. haemorrhoidalis is easily distinguished by the bright orange red on the tip of the abdomen. The thorax above is olive gray and hairy, with a black band behind the suture. The base of the abdomen is whitish and the middle blackish, which is in strange contrast with the orange red of the end. It deposits only upon the small hairs on the lips of horses and mules.

FIG. 2.—*Gastrophilus haemorrhoidalis:* Female. Oviposits only upon the small hair on the lips of horses, preferably the portions moistened by saliva. Greatly enlarged. (Original.)

The males of *G. intestinalis* and *G. haemorrhoidalis* are often found awaiting the approach of females to the horses, and when they arrive the flies copulate.

The species characteristics of the eggs of the three species occurring in the United States can best be observed by referring to the illustration (fig. 3). While *G. intestinalis* is usually attached about one-half its length to the hair, *G. nasalis* is attached almost its entire length. *G. haemorrhoidalis* is always found attached to the base of a hair on the lips. These hairs are so small that one does not observe them with the naked eye. It is the only Gastrophilus depositing here. The egg is black in color and the stalk is partially inserted in the pore of the skin at the root of the hair.

Fourth-stage lavæ, as can be seen in the illustration (Pl. I), vary in size when fully developed. In all specimens the eleventh ring is completely deprived of spines, but upon the other rings the variations are often misleading. However, the key given herein will assist in identifying fully developed larvæ.

KEY FOR THE IDENTIFICATION OF FULLY DEVELOPED LARVÆ OF GASTROPHILUS SPP.

1. Spines arranged in two alternating rows, the first more developed than the second 2
   Spines in one row ..... *G. nasalis.*
2. Spines long and prominent, lacking only two to three pairs on dorsal center of the ninth row ..... *G. intestinalis.*
   Spines short and segments prominent. Completely deprived or possessing only two to three pairs of spines on either side of the dorsal center of the ninth ring ..... *G. haemorrhoidalis.*

DISTRIBUTION IN THE UNITED STATES AND PROBABLE DISPERSION.

Recently Mr. F. C. Bishopp, in communication with a large number of horse breeders, has determined some facts on the distribution and other points, especially in regions adjoining the district where *G. haemorrhoidalis* is known to occur. This information will be published later. It will suffice to say here that *G. haemorrhoidalis* occurs in sufficient numbers to warrant the adoption of control measures in the Dakotas, Montana, and northern Wyoming. According to Dr. C. Gordon Hewitt, Dominion Entomologist, the species extends over a considerable area in the Dominion of Canada. Two of the species, *G. intestinalis* and *G. nasalis*, are found throughout the United States where horses are present. *G. pecorum* is not known to occur in the United States.

The constant migration of the larvæ of *G. haemorrhoidalis* to the region of the anus and their dropping, which occurs over a long period, indicates that the principal means of dispersion is through the movement of infested horses. During the past few years large numbers of horses, which have been purchased in the infested district for European army purposes, were concentrated at certain points until more could be assembled for shipment. This occurred at times when larvæ were normally dropping and allowed ample time for this species to become established. Although the adults may not have appeared in sufficient numbers to attract attention in new districts, this will undoubtedly occur in the near future.

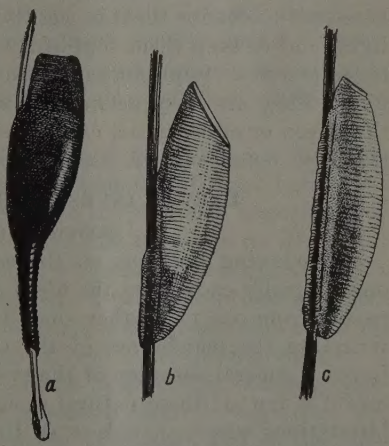


FIG. 3.—Gastrophilus eggs attached to hairs: *a*, *G. haemorrhoidalis* and hair removed with root; *b*, *G. intestinalis*; *c*, *G. nasalis*. Greatly enlarged. (Original.)

The comparatively short duration of adult life and the functions of the adults restricted to depositing eggs indicate that little dispersion takes place by actual flight. In the nose-fly district there has been a slow but gradual spread of the species each year, as verified by hundreds of statements from farmers and horse breeders.

LARVAL COLLECTIONS AND REARING TECHNIQUE.

An insectary was located in Aberdeen, S. Dak., where all types of farm and city operations concerned with the use of horses could

be observed, and at the same time easily accessible to a rendering plant where post-mortem examinations could be made. Horses in pasture were available in all directions, and livery barns were located within a mile and could be conveniently visited.

Horses of many types, representing every locality in the immediate vicinity, could be observed in the livery barns, and it was from these horses that breeding material of *G. haemorrhoidalis* was obtained. While examinations of droppings were made, most of the larvæ utilized were removed from their places of attachment about the anus. These were sufficiently developed to pupate and produce adults, and did so even though they were not handled carefully with the forceps in removal. The number of horses in the liveries varied, but usually from 30 to 100 were observed daily. In order to obtain an ample supply of larvæ additional collections were made when near-by farmers came in with teams.

In rearing adults, the larvæ were placed in tin boxes upon moist sand in California parasite-rearing boxes, or in bread trays upon grass sod. These were usually kept in cages 18 by 18 by 18 inches, each of which was fitted with a door of sufficient size to permit the removal of trays for examination. When adults emerged it was necessary to confine them in tightly fitted cages which excluded sunlight, and to keep them supplied with grass sod or green foliage to lessen activity. Sunlight has an unusually great attraction for adult flies. They are very active and will damage their wings against the screen or crawl into a cage crevice and die. More especially has this been noted with *G. haemorrhoidalis*.

LARVAL INFESTATION AND INJURIES.

REVIEW OF OPINIONS.

In reviewing opinions on the economic importance of bot-flies, one naturally encounters the ideas of Bracy Clark, which have been passed from one to another since 1798. He believed that larvæ by irritating the membranes of the stomach and intestines often relieved a general disorder of the system, but mentions that, however useful a few of these natural stimuli may be, they result in large infestations which should at all times be prevented. He indicates in this paper that the infestations coming under his observation did not greatly exceed 100 larvæ, and for the most part not more than a half dozen were to be found.

We find the following statement by R. S. MacDougal (1899):

> Opinion differs a good deal as to the harmfulness of these bots. In conversations with veterinary surgeons I find there is a tendency to minimize the evils that may attend bot presence. There are authenticated records, however, which place the possibility of grievous harm beyond all doubt. Inflammation, ulcers, interference with digestion, interference with the free passage of food or exit of waste matters, loss of appetite and condition, have been frequently

Warburton (1899) says:

> The irritation they set up can not fail, however, to be detrimental to the horse's health even where no ill effects are obvious. The fact seems to be that a horse in good condition and well fed can endure the presence of numerous bots in the stomach without great inconvenience, but if the animal is in poor condition gastric enteritis, perforation of the stomach, and death may result.

In Miss Ormerod's report of 1890, Dr. Hy. Thompson, of Aspatria, Cumberland, England, says:

> I have never seen the stomach entirely perforated, but the irritation induced by the development of the larva causes in many cases a great wasting of flesh in the horse.

Perroncito (1902) describes lesions caused by Gastrophilus larvæ, some of which resulted in perforation of the stomach walls and death of the animals. Cases of Flohill, Numan, Conti, and others, as well as cases coming under his personal observation, are mentioned.

Kröning (1906) reports having observed cachexia accompanied with colic in young colts during the previous five years, and attributes this to infestations of bots.

Lahille (1911) makes mention of larvæ causing death of animals and cites the possibility of infection in the lesions.

Velu (1913) reports that a drought greatly favored attacks in Morocco and more than 1,000 larvæ were usually found in post-mortem examinations. All three of the more common species were present, but *G. nasalis* caused lesions which resulted in death of the animals.

The universal distribution of *G. equi* and *G. nasalis* has familiarized persons in every locality to some extent with bots of horses, yet their opinions are naturally varied as to the economic importance of the larvæ. There are some who believe that there are no ill effects; others think that they are beneficial; while some even believe that a horse will die if the bots are removed. Such conceptions are most prevalent among "horse doctors" who are not in possession of an effective treatment for the removal of bots. On the other hand, it is a difficult matter to convince a horse breeder that bots are beneficial when his yearling colts kept in pastures have a rough coat, fail to grow or fatten, show no symptoms of disease, and at the same time possess a good appetite. Many breeders have made post-mortem examinations of horses for their personal satisfaction. The finding of hundreds of well developed larvæ with conspicuous lesions conveys vivid impressions and greatly emphasizes the importance of bots. Others, without a knowledge of the development of bots within the horse, often make examinations after numbers have been passed and the lesions healed; or when the larvæ are small and probably not observed by an untrained eye they are regarded as less detrimental. It is only by careful post-mortem examinations of large numbers of

horses that conclusions can be drawn, and these may be erroneous if one is not familiar with the various species, their usual points of attachment, and phenomena peculiar to each.

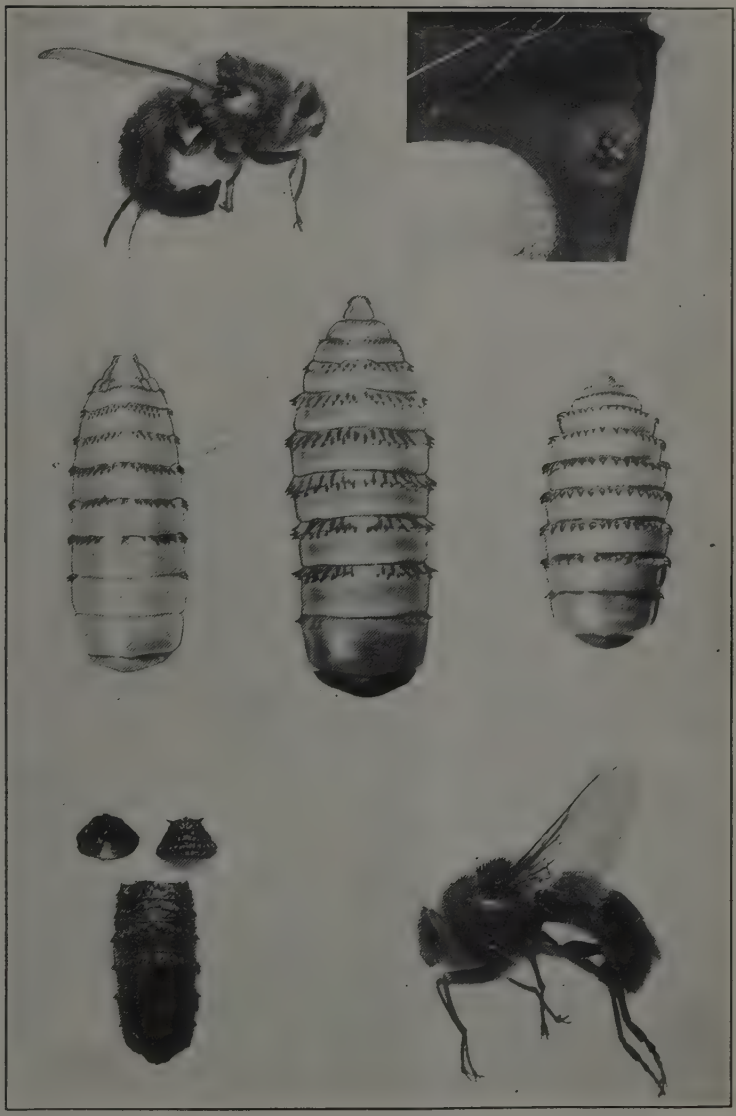
SPECIES IMPLICATED.

Gastrophilis intestinalis, "the common bot," attaches ordinarily in the stomach, has been taken in the duodenum, but has never been found permanently attached in any other regions (Table I, p. 10). Rarely it may become temporarily attached in the rectum, but is not present with an alveolus or lesion.

G. nasalis, "the throat bot," attaches by preference in the duodenum, is often found in the stomach, and is the only known species which attaches in the pharynx. Due to the attachment in the throat, it not only becomes a species of vital importance when the bots congregate in sufficient numbers to hinder or cut off the breathing of the horse or cause an infection, but in this location they can not be removed by an internal treatment. In the duodenum the infestation may be sufficient to hinder or stop the passing of excreta. Table I (p. 10) shows the comparative abundance in the stomach and duodenum during the period that larvæ are well developed and naturally drop from the host.

Various cases are on record in which this species has been removed from the pharynx, in all of which the authors considered it a serious detriment to the horse. While larvæ which were not sufficiently developed to be determined with authenticity have frequently been removed from the pharynx, 8 larvæ of *G. nasalis* were collected in the throat of a dray horse by J. L. Webb at Reno, Nev., on August 29, 1916. In numerous cases, both at Aberdeen, S. Dak., and at Dallas, Tex., the author has found lesions present in the pharynx, indicating that the larvæ had become fully developed and had passed out of the horse. In making post-mortem examination of horses to determine the attachment of young larvæ in the pharynx extreme care should be exercised, as young meat-infesting larvæ may be confused with Gastrophilus. Upon hatching they migrate from the light into the nostrils and may be found in the pharynx and other locations in the throat.

Dr. Buffington (1905), of Brooklyn, Iowa, gives a valuable history of a case in which a mare died as the result of an infestation of *G. nasalis* in the pharynx. This animal had experienced difficulty in eating for more than a month, and was unable to take food for a week prior to November 26, 1903. At this time she would drink water, but after masticating food a very little, would drop it out. The symptoms were those of paralysis of the muscles of deglutition and there was a very offensive odor about the head. Four days later, when the animal died, the nasal, pharyngeal, laryngeal, and upper portion of the œsophageal mucous membranes were found to be gan-



STAGES OF THE BOT FLIES, GASTROPHILUS.

Upper left.—*Gastrophilus haemorrhoidalis:* Female, side view. Upper right.—*G. haemorrhoidalis.* Larvæ attached to margin of anus of horse. Left of center.—*G. haemorrhoidalis:* Last-stage larva. Center.—*G. intestinalis:* Last-stage larva. Right of center.—*G. nasalis:* Last-stage larva. Lower left.—*G. intestinalis:* Puparium, showing cap split off by fly in emergence. Lower right.—*G. haemorrhoidalis:* Male, side view. (Original.)

LARVÆ OF THE BOT FLIES, GASTROPHILUS.

Upper.—Attachment of last-stage larvæ and alveolar lesions upon the mucosa of the left sac of the stomach. Lower.—Infestation of 317 last-stage larvæ, with lesions in the center. (Original.)

grenous and the source of the offensive odor. From the pharyngeal walls 12 or 15 larvæ were removed, 6 of which the present author obtained. Three of these larvæ were determined as *G. nasalis*, and it is reasonable to believe that the other larvæ, which were not sufficiently developed for identification, were of the same species.

The larvæ of *G. haemorrhoidalis*, "the nose-fly," as is shown in Table I, may be found in the stomach, duodenum, or rectum, and also attached about the margin of the anus, where they change in color from pink to a greenish, become accustomed to the atmosphere, and later drop to the soil for pupation. During the early stages they attach within the stomach and duodenum, but later loosen themselves and reattach in the rectum, from which they gradually move to the anus. The attachment of clusters of these larvæ in the rectum has been known to stop the passage of excreta and to cause abnormal protrusions accompanied by much suffering.

About June 1, 1915, a horse breeder in Montana experienced a case of obstruction of the rectum in a yearling colt. On three different occasions within one week the animal was observed lying down in the pasture with the rectum greatly protruded. Each time it was washed with warm water and replaced, but the larvæ causing it were not observed until the third time. The exact number of bots removed by hand was not ascertained, but upon their removal and replacement of the rectum the animal gradually recovered.

Table I records a maximum of 1,032 bots removed from a 2-year-old colt. The infestation consisted of 695 *G. intestinalis*, 248 *G. nasalis*, and 89 *G. haemorrhoidalis*. This was the greatest number obtained during any of the autopsies. Colts are always the most heavily infested, especially when they come from summer pastures, and in this case the animal was greatly emaciated, possessed a dull coat, and, in spite of a good appetite and an abundance of food during the previous winter, failed to grow or fatten. It had suffered from a broken shoulder, the result of a kick, which ordinarily would have healed promptly at this age, but instead it remained for months a cripple. The owner, believing that it would never thrive, caused the animal to be killed, and the post-mortem examination revealed no abnormal condition, except the bot infestation and the broken shoulder. It appeared that so much vitality was sapped through the inroads of bot infestation that the colt had no recuperative surplus.

At the date of the post-mortem examination 89 *G. haemorrhoidalis* larvæ had migrated to the rectum and attached. They were not sufficiently developed to pass out and were attached at this point with lesions characteristic of those usually found in the stomach.

In Table I many of the infestations noted were comparatively small when the post-mortem examination was made, and attention should be called to the fact that all of these examinations were made

during the time when larvæ were naturally dropping with excreta. The numbers do not show the maximum infestations of larvæ that may have been present. Many of the dead horses examined had been subjected to various environments prior to the autopsies and are not representative of infestations found when horses have spent the entire previous summer in pastures.

TABLE I.—*Gastrophilus findings in post-mortem examinations of horses at Aberdeen, S. Dak., 1915–16.*

Horse died.	Spent summer.	Larvæ in stomach.				Larvæ in duodenum.				Larvæ in rectum, G. haemorrhoidalis.	Total number larvæ.
		G. intestinalis.	G. nasalis.	G. haemorrhoidalis.	Gastrophilus sp. small.	G. intestinalis.	G. nasalis.	G. haemorrhoidalis.	Gastrophilus sp. small.		
1915.											
June 7		295	11	21	.....	.....	.....	.....	.....	9	[1] 337
July 8		158	.....	12	.....	.....	.....	.....	.....	14	184
July 14		103	.....	1	.....	11	1	.....	.....	.....	116
July 21		58	290	3	.....	.....	.....	.....	.....	.....	351
July 26	Driven on streets	33	.....	.....	.....	.....	.....	.....	.....	1	34
Aug. 12	....do	18	.....	.....	.....	.....	.....	.....	.....	.....	18
Aug. 23	....do	6	.....	.....	10	.....	.....	.....	.....	.....	16
Aug. 23	In pasture, 1915	.....	.....	.....	67	.....	.....	.....	.....	.....	67
Aug. 26		9	1	.....	35	.....	.....	.....	.....	.....	45
Aug. 26	In pasture, 1915	5	.....	.....	71	.....	.....	.....	.....	.....	76
Aug. 26		.....	.....	.....	42	.....	.....	.....	.....	.....	42
Sept. 13	Country and town driving	.....	.....	.....	217	.....	.....	.....	.....	.....	217
Sept. 17		.....	.....	.....	101	.....	.....	.....	71	.....	172
Sept. 20	Driven on streets	.....	.....	.....	.....	.....	.....	.....	22	.....	22
Sept. 21	....do	1	.....	.....	4	.....	.....	.....	13	.....	18
Oct. 1	Farm work	6	.....	.....	50	.....	.....	.....	82	.....	138
1916.											
May 20	....do	123	15	7	.....	.....	.....	.....	.....	.....	145
May 20		7	.....	.....	.....	.....	.....	.....	.....	.....	7
May 29		56	1	10	.....	.....	.....	.....	.....	.....	67
May 29		44	10	35	.....	.....	22	.....	.....	.....	111
June 7		64	.....	.....	.....	.....	5	2	.....	.....	71
June 8		18	.....	5	.....	.....	19	.....	.....	.....	42
June 16		16	.....	1	.....	.....	.....	.....	.....	.....	17
June 21	Driven on streets	3	.....	.....	.....	.....	.....	.....	.....	.....	3
June 26	In pasture, 1915	687	70	.....	.....	7	178	.....	.....	89	[2] 1,032
June 28	....do	72	2	26	.....	.....	137	.....	.....	.....	237
July 11	Farm work	116	2	.....	.....	.....	19	1	.....	.....	138
July 17	....do	92	5	.....	.....	.....	144	.....	.....	.....	241
July 24	In pasture	461	.....	.....	.....	.....	149	.....	.....	.....	610
Aug. 3	Farm work	151	1	1	.....	.....	.....	.....	.....	.....	153
Aug. 4		39	16	4	.....	4	30	.....	.....	.....	93
Aug. 7		20	.....	.....	.....	.....	25	2	.....	.....	47
Aug. 6		.....	.....	.....	13	.....	1	.....	.....	.....	14
Aug. 11		24	.....	.....	.....	.....	.....	.....	.....	.....	24
Aug. 11		29	14	1	.....	.....	4	.....	.....	.....	48
Aug. 23		1	.....	.....	6	.....	.....	.....	26	.....	33
Aug. 23		44	.....	8	8	.....	26	.....	16	.....	102
Aug. 26		23	.....	.....	.....	.....	1	.....	12	.....	36
Sept. 1		1	.....	.....	20	.....	.....	.....	.....	.....	21
Sept. 8		2	.....	1	1	.....	.....	.....	14	.....	18
Sept. 11		5	.....	.....	.....	1	.....	.....	.....	.....	6
Sept. 16		2	.....	.....	37	.....	.....	.....	31	.....	70

[1] Includes 1 *G. intestinalis* temporarily attached in colon.
[2] Includes 1 *G. intestinalis* temporarily attached in rectum.

LARVAL MOVEMENTS WITHIN THE HORSE.

When a post-mortem examination is made, the larvæ usually are found quiescent, although occasionally some may be observed to move the posterior end slightly. The smaller larvæ show more activity than do well-developed ones.

Other than *G. nasalis*, which sometimes attaches in the pharynx, the first-stage larvæ attach to various portions of the stomach and duodenum. In the stomach young larvæ have been removed from various locations, including both the cardiac and pyloric portions. The last-stage larvæ of all three species are found in the various portions. *Gastrophilus intestinalis* is confined for the most part to the mucosa of the left sac, though this species has been taken in the right sac and in the duodenum (see Table I). In the early stages some of the larvæ either change places of attachment or pass out of the horse undeveloped. With last-stage larvæ the indications are that, excepting *G. haemorrhoidalis*, they remain attached at one place continuously during feeding, as in early spring the number of larvæ and lesions upon the mucosa is the same.

During the early spring or perhaps even in winter the larvæ of *G. haemorrhoidalis* move from the stomach and duodenum to the rectum where they may be found permanently attached in clusters. It is evident that they feed in this position, as lesions are sometimes present. Later when they move to the margin of the anus no lesions are present and apparently the larvæ only pause to become accustomed to air temperatures before dropping.

There is no definitely periodic larval migration of *G. haemorrhoidalis*, as some last-stage larvæ are found in the stomach and duodenum until early fall. Through the courtesy of Dr. L. Van Es, of the North Dakota Experiment Station, some post-mortem examinations were made at Fargo, N. Dak., and larvæ preserved according to their location within the animal. During the winter these larvæ were found in the stomach, and on July 10, 1916, 3 larvæ; July 14, 1916, 16 larvæ; and August 18, 1916, 2 larvæ were fully developed and in the same regions. This coincides with the findings at Aberdeen, S. Dak., although one last-stage larva was found in the stomach on September 8, 1916.

POINTS OF LARVAL ATTACHMENT.

When an opened stomach of a horse is examined, one is impressed by the contrast in the left and right portions. Around the entire organ a line of demarcation is represented by a prominent sinuous crest. In the left portion, which is often called the left sac, the mucosa is white, dry, resistant, and covered by a thick layer of epithelium. This covering is identical with that of the esophagus and may be considered as a widening of the esophageal canal.

Dr. Guyot, in describing the mucosa of the left sac, says the structure is analogous to that of the skin. It is dermo-papillary, with epithelium of the Malpighian type, but possesses a muscle, the *muscularis mucosae*, which is peculiar to it. The structure of the

right sac differs in having a soft membrane with an epithelium formed by a single layer of cells.

G. intestinalis larvæ are practically always found attached in the left sac, and it is the opinion of Dr. Guyot that this portion affords the most stable point for larval attachment. He thinks that cases are exceptional in which larvæ maintain themselves in the right sac. This, however, does not explain the attachment of *G. nasalis* in the duodenum and to the walls of the pharynx, nor does it account for the attachment of *G. hæmorrhoidalis* in the right sac of the stomach, in the duodenum, or in the rectum. As has been mentioned by Dr. Guyot, the reason for attachment in certain regions of the digestive tract will remain a mystery until the manner in which larvæ are nourished is ascertained.

Various investigators have been unable to discover white or red corpuscles of the horse in the pharynx and other alimentary portions of the larvæ. Clark believed their food was probably the chyle, but Guyot rejects this explanation, as larvæ in the pharynx are located where this could not possibly be utilized. As *Oestrus ovis* larvæ nourish themselves with the mucus secreted by the mucosa of the nose and frontal sinuses of sheep, and as those of Hypoderma utilize the pus of the abscesses which they create by their presence in cattle, he believes it permissible to suppose that those of Gastrophilus find nutriment in the inflammatory products of the gastric mucosa.

It would appear, from observations, that Gastrophilus larvæ sometimes feed upon the blood of the animal, although they are not dependent upon it for subsistence. The red and maroon color of *G. intestinalis* and *G. hæmorrhoidalis*, with their attachment upon points other than the mucosa of the left sac, would bear out this hypothesis, which is further supported by the fact that *G. haemorrhoidalis* when fully developed in the rectum still retains a pinkish color.

THE ALVEOLAR LESIONS OF THE STOMACH.

In Dr. Guyot's examinations of lesions caused by the attachment of larvæ to the mucosa of the left sac, the muscular coat was not damaged. The condition found was merely a localized inflammation around the point of larval attachment, in which the derma had been invaded by leucocytes. He assumes that this is only the common inflammatory reaction which would be normally produced around any foreign body.

In following these studies Perroncito found that the bottom of the alveolus varied in size and became the seat of a more or less remarkable inflammatory process. This produced a thickening of the walls of the stomach and finally the disappearance of the muscular tissue, which becomes hard and compact, preventing the normal functions of

the stomach. He mentions cases of perforations, lacerations, and ruptures of the stomach observed by Flohill, Numan, Conti, and Brusasco, and calls attention to alveolar lesions which are naturally more predisposed to induce various infective diseases. (See Plate II.)

GASTROPHILUS AND SWAMP FEVER.

Aside from the lesions which may induce the entrance of organisms of infectious diseases, the Seyderhelms, of Strassburg (1914), report results which they think implicate Gastrophilus larvæ in the causation of swamp fever. It is believed by them that the larvæ excrete a specific toxin which is the cause of the disease, for by administering extracts of these larvæ symptoms typical of swamp fever have been observed. The coincidental distribution of Gastrophilus with that of this disease would appear to bear out the hypothesis. It is said that the most virulent reactions were obtained in these experiments with *G. haemorrhoidalis* larvæ.

BOT-FLY ANNOYANCE.

In those portions of the country where the nose-fly does not occur, horses are seldom sufficiently annoyed to require protection. The persistence of the common bot-fly and the repeated stamping of the animals are evidence that it is annoying, but when the throat bot-fly "strikes" the action of the horse becomes more violent.

The throat bot-fly is less persistent but more determined in depositing, and the horse usually responds with a violent nod or jerk, the violence depending upon the nervousness of the individual. In plowing it is sometimes necessary to place a strip of cloth or a small branch of a tree underneath the throat latch and extending to the bit rings.

In the nose-fly section the annoyance is produced by the two generally distributed species in addition to *G. haemorrhoidalis*. Upon the approach of this fly the horse moves the head backward and forward to prevent its darting on the lips, but this only seems to arouse its determination, for it quickly alights on the lips and within a second or two deposits a black egg. It apparently occasions a most annoying sensation, and a horse will most often snort and rub violently against the ground, a bowlder, a tree, barb-wire fence, or any convenient object.

The effects of ovipositions on pastured animals are worry, loss of flesh, and mechanical injuries. If the lips are examined barb-wire lesions will be found which resulted from the rubbing of the horse following an oviposition. (See Plate IV.)

With an unprotected work animal one may be suddenly confronted with a jerk or a similar violent action of the animal at each oviposition of the fly. When a few eggs have been deposited the animal

proceeds from infuriated shaking of the head, sometimes accompanied by loud snorts, to complete loss of self-control, and will use any means for self-protection. Numerous runaways naturally occur and serious accidents have also occurred when horses were being used for mowing. The majority of farmers and breeders contend that "the fly stings the horse in the nose." The reactions of the animals are often so violent that at first it seemed that the horses really experienced pain. Dr. Parker, of the Montana State Board of Entomology, has published some notes[1] to the effect that the eggs were thrust into the skin, but he failed to recognize the minute hairs to which the eggs are attached. The pointed portion of the egg is merely a device by which it is attached to the hair. A horse does not experience any pain, as the ovipositions do not puncture the skin. Neither do the flies deposit in the nostrils. Careful search has failed to disclose a single egg in such locations, and it would appear that the snorting of the animal has given rise to this "popular opinion." It is believed, however, that annoyance is largely due at first to an instinctive fear and later to a tickling sensation when the eggs are attached to the minute hairs, as the lips are the most sensitive portions of the horse. Practically all horses in this section have sore lips from eating a "wild barley" or "foxtail grass" (*Hordeum jubatum*) and there is no doubt that this soreness contributes to the annoyance.

NATURAL PROTECTION OF HORSES.

The flies show no preference as to type, breed, color, or age, but naturally oviposit upon unprotected animals. Horses seek protection in pastures, the individuals gathering in a bunch and resting their lips upon one another. Colts and young animals not high enough to protect their lips in this way receive an abundance of eggs.

A horse will sometimes hold the lips upon the ground as if grazing, upon detecting the presence of the fly, and when held in such position the adult fly is rarely observed to oviposit. Often the annoyance of biting flies and other depositing Gastrophilus will cause a horse to walk, holding the lips near the ground. Frequently other horses will follow and protect themselves by placing their lips upon his back or the backs of other animals in the line. Usually they search for the highest elevation where the breeze is blowing, or for standing water, but if an open stall is convenient they will use it to good advantage. If protection is not found an unconfined animal will often wander a great distance from home.

Upon a bright still day ovipositions occur from 8 a. m. until about sunset, and the group of horses may be observed to shift from place

[1] See "Bibliography," page 50.

to place without eating, their lips resting upon one another, or they may congregate with cattle, which are not subject to attack. The horses spend such days in awaiting darkness, after which feeding takes place. Characteristic positions of the animals are shown in Plate III.

Wind with a velocity of 15 miles an hour or more greatly relieves the animals, and persons driving horses about thrashing machines often stop them so that they face the breeze.

Cloudiness is also a protection to horses, and if only a light cloud conceals the sun a bunch of horses may be observed to disperse and begin grazing. Often their feeding will have only begun when the sunlight returns, causing them again to seek protection in a group.

Horses in standing water are not annoyed by nose flies and frequently they seek this protection in order to eat, despite the fact that hundreds of mosquitoes feed upon each animal. This standing or feeding upon grass in water is excellent for a foundered horse, and the mud which adheres to his legs prevents *G. intestinalis* from ovipositing upon them.

While the wind and cloudiness are especially protective against *G. haemorrhoidalis*, the other two species of bot-flies are not much affected thereby. *G. intestinalis* may be observed to oviposit on windy and cloudy days. *G. nasalis* deposits under more adverse conditions than does *G. haemorrhoidalis*, but seems to be more sensitive to natural agencies than is *G. intestinalis*.

In barns the species of Gastrophilus never have been observed to oviposit. On numerous occasions ovipositing adults have been observed to pursue the animal only until it reaches the stall door. Post-mortem examinations of horses which had been confined in stalls failed to reveal a single larva. One of our correspondents reports that the annoyance of *G. haemorrhoidalis* was greatly reduced when he constructed a simple shed in the pasture where the horses could congregate.

SEASONAL HISTORY OF GASTROPHILUS.

At Aberdeen, S. Dak., the larvæ of *G. haemorrhoidalis* are observed attached to the margin of the anus of horses as early as May 5 to 10, and if suitable temperatures occur adults may be expected a little prior to June 15.

From June 21 to 27, 1915, *G. haemorrhoidalis* adults appeared at Lodge Grass, Hardin, Billings, Miles City, and Custer, Mont. At the same time they appeared at Aberdeen, S. Dak., and neighboring points. They have been observed at Aberdeen, S. Dak., as late as October 10, though they are seldom found after a killing frost, which is usually about September 15.

The other two species appear at Aberdeen, S. Dak., about the same time as *G. haemorrhoidalis*, but are most abundant just before a killing frost. The *G. haemorrhoidalis* are least abundant at this time, and are present in greater numbers during the early half of the season. After a killing frost one seldom finds a Gastrophilus except when warm temperatures prevail during a few days.

In the "nose-fly" district one must bear in mind that the period during which flies oviposit is that when farmers are most busy, and the most favorable time for fly ovipositions is when the weather is most favorable for working horses. The adults appear during the plowing of corn and sorghum, and the annoyance continues during the mowing of hay, the harvesting and thrashing of grain, and the marketing of farm products.

GASTROPHILUS HAEMORRHOIDALIS (Linnaeus).

SYNONYMY.

Oestrus haemorrhoidalis Linnaeus, 1761.
Gastrophilus haemorrhoidalis Leach, 1817.
Gastrus haemorrhoidalis Meigen, 1824.

ATTACHMENT IN RECTUM AND DROPPING OF LARVÆ.

During the early spring and summer the fourth-stage larvæ are normally concealed within the rectum, where lesions have been noted in post-mortem examinations. Later they effect a temporary attachment to the margin of the anus, where they become accustomed to the air temperatures, assume a greenish color, and apparently increase their motility. Larvæ, normally exposed to the air at the rectum, after dropping seem to conceal themselves at grass roots so as to be protected from the heat of the sun much more easily than those unexposed at the margin of the anus. When a larva is attached so that only the posterior end is exposed at the rectum one will find the anterior end a pinkish color, while the posterior will be greenish.

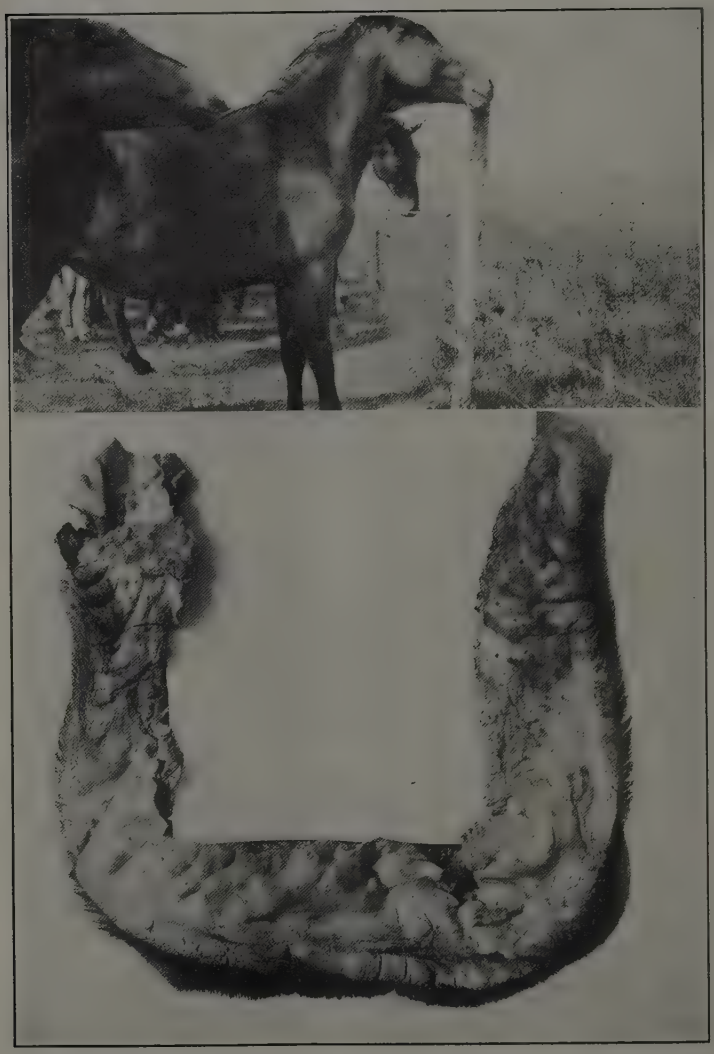
Larvæ exposed at the rectum have been observed for the length of time they remain attached, and the shortest period was slightly more than 40 hours, while the longest was 71 hours. The heat of the sun for a few minutes was sufficient to cause larvæ to drop when an attempt was made to photograph a larval attachment at the anus. At various times during the day larvæ appear at the anus, as many as 13 sometimes being visible at one time. The larvæ are likely to drop under most any condition, but do not drop with manure, as is supposed. When manure is dropped during their attachment they seem to use more effort in clinging and are only pushed aside during its passage. (See Plate I, figure at upper right.)

PREPUPATION AND PUPAL PERIODS.

In the normal pupation of a larva which has been exposed at the margin of the anus there is a gradual change from greenish to yel-

PROTECTION FROM BOT FLIES.

Upper.—Horses assembled for protection during ovipositions of *Gastrophilus haemorrhoidalis*. Center.—A method of protecting lips from ovipositing *G. haemorrhoidalis*. Lower.—Protecting under jaws from ovipositing *G. nasalis*. (Original.)



SECONDARY INJURY FROM BOT FLIES.

Upper.—Horses rubbing following ovipositions of *Gastrophilus haemorrhoidalis*. Lower.—Lower lip of horse showing barbed wire cut at the lower extremity which resulted from rubbing. The small holes are injury from the grass *Hordeum jubatum*. (Original.)

lowish, the larva contracting and assuming the form of a pupa. As the puparium becomes more hardened a reddish tinge appears, but after a few days it becomes black and retains this color until the adult emerges.

TABLE II.—*Some environmental effects on metamorphosis of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak.*

Larvæ collected from rectum.	Environment.	Prepupal period.	Pupal period.	Temperature, collection to emergence.			Number larvæ.	Number pupæ.	Number adults emerged.	Longevity of larvæ not pupating.
				Max.	Min.	Mean.				
1915.		*Hours.*	*Days.*	° *F.*	° *F.*	° *F.*				*Days.*
June 4	Fresh horse manure in tin box	27–47	39–45	88	35	63.21	14	14	10	.....
June 5	.....do.....	24–72	46–54	88	35	64.76	33	31	22	4
June 7	.....do.....	34–52	37–44	88	35	64.93	16	13	8	8
June 8	.....do.....	49	38–40	88	35	65.67	7	7	2	.....
June 9	Clean tin box.....	35–55	36–48	88	35	65.02	12	11	9	.....
June 12	Glass jar and fresh horse manure.....	53–146	33–36	88	40	65.73	14	14	5	.....
June 15	Dry hard soil.....	75–122	28–30	85	40	62.40	10	10	5	.....
Do...	Moist horse manure.....	122	29–31	85	40	62.56	10	8	7	15–22
Do...	Clean tin box.....	120	31–32	84	40	62.89	7	6	4	15
June 14	.....do.....	50–144	30–38	84	40	64.33	27	25	18	16
June 18	.....do.....	27	32–42	84	40	63.23	34	30	26	12
June 17	Moist manure in tin box.....	18–47	34–40	84	40	62.06	33	33	28	.....
July 12	Black loam in tin can.....	23–39	34–35	85	40	64.23	8	5	2	.....
Aug. 7	On grass sod.....	19–26	58–68	88	[1] 32	60.59	7	7	3	.....
1916.										
May 22	Clean tin box.....	68	41	94	42	62.62	5	4	4	.....
May 23	.....do.....	52–72	36–40	94	42	62.81	5	4	3	11
May 30	.....do.....	141–170	34–35	94	42	64.79	2	2	1	.....
May 31	.....do.....	.....	35	94	42	60.08	1	1	1	.....
June 3	.....do.....	42–96	33–34	94	42	65.55	11	8	5	5
June 5	With moist sand.....	75–100	32–35	94	42	66.69	17	17	16	.....
June 10	.....do.....	44	30–32	94	42	68.15	28	25	20	4
June 23	Clean tin box and moist loam.	.....	21–24	96	48	74.08	46	44	38	5

[1] Minimum, Sept. 21.

In rearing larvæ to adults a most convenient and efficient method was utilized by placing them in clean tin salve boxes upon moist sand in bread pans. Table II gives some results of rearing under such conditions, using various media within the tin boxes. The period of collections extends from June 4 to August 7, which includes practically the entire season during which larvæ appear at the anus of horses in Aberdeen, S. Dak. It will be observed that the prepupal stage, the period from removal of larvæ until pupation, varies from 18 to 170 hours. This is a much greater range of time than is normal and may be attributed to the fact that larvæ were removed before the critical period of dropping. In some instances under varying conditions they did not pupate, and, while some larvæ died within a few days, one is recorded as living for 22 days.

The removal of larvæ from the rectum prior to their normal exposure to the air at the margin of the anus has a pronounced effect upon rearing. A small percentage have been reared which were fully

developed and concealed within the rectum, but larvæ less than normal size, which were not exposed at the margin of the anus, did not produce adults. Only larvæ possessing the greenish color indicating exposure at the margin of the anus were used in experiments recorded in the tables.

In Table II, of 347 larvæ collected, 319 pupated and produced 236 adults, the pupa period varying from 21 to 68 days. The greater portion emerged during the shorter periods indicated in the table.

FATE OF LARVÆ DROPPING UNDER VARYING CONDITIONS.

The variety of conditions under which larvæ are dropped naturally suggests the question of their ultimate fate. In an effort to determine this point by experiments, the most striking phenomenon observed was the larval "migration" which precedes pupation. In experiments recorded in Table III, larvæ placed upon the surface of the soil or media penetrated to a slight depth for protection of the pupæ. With larvæ buried in loose soil, as would ordinarily occur when they are dropped by plow horses, they moved upward to near the surface for pupation.

TABLE III.—*Natural pupation and artificial burials of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

Larvæ collected from rectum.	Environment.	Condition of soil.	Depth pupated.	Number larvæ.	Number pupated.	Adults emerged.		Period, collection to emergence.	Temperature, collection to emergence.		
						Male.	Female.		Max.	Min.	Mean.
1915.								*Days.*	° *F.*	° *F.*	° *F.*
June 10	On 2 inches fresh horse manure over 2 inches of loam.	Moist manure developed a mold.	Burrowed ½ to 1 inch in compact manure.	17	17	7	5	35–41	88	40	66.10
Do	On 2 inches dry horse manure over 2 inches of loam.	Very dry horse manure	Upon and near surface	17	16	8	4	35–40	88	40	66.06
June 15	On dry, hard soil	Kept dry	At surface	10	10	2	3	31–33	85	40	64.94
Do	On moist manure	Kept moist	½ to 3 inches deep	10	8	2	5	34–36	85	40	64.93
June 16	Buried under 4 inches black loam and fresh horse manure intermixed.	Pulverized by Lachnosterna larvæ.	3 pupated at surface	15	14	4	4	31–40	85	40	64.03
Do	Buried under 4 inches decaying straw and manure intermixed.	Fairly moist	Few near surface	15	15	6	1	33–40	85	40	64.56
June 19 [1]	Buried under 3½ inches black loam.	Fairly moist and compact	4 near surface	35	35	6	9	30–35	85	41	64.91
Do	On grass sod	Fairly moist	In crevices and near surface	35	35	19	13	34–41	85	40	63.81
July 9 [2]	On wet black loam	Kept wet	Near surface	17	8	1	1	35–36	85	40	63.95
1916.											
June 15 [3]	On grass sod	Kept moist	Near surface	21	19	1	2	32–34	96	42	70.74
June 17	Buried under 5 inches loam	Slightly moist	Pupæ placed 5 inches below surface.	38	32	14	15	24–31	96	42	71.34
July 10	On grass sod	Kept slightly moist	Near surface	43	42	20	18	23–24	98	53	71.66

[1] Pupæ decayed.

[2] 9 larvæ died; other pupæ decayed.

[3] Mouse ate contents of several puparia.

Questioning the fate of pupæ if buried, a lot consisting of larvæ that had moved near to the surface before pupating were replaced in moist loam to a depth of 5 inches. The adults had no difficulty in penetrating this soil, as 29 emerged normally from 32 pupæ. A lot of 15 larvæ buried 4 inches under black loam and fresh horse manure produced 14 pupæ, many of which were located near the surface. Lachnosterna larvæ were present and during their development kept the soil well pulverized. Of the 14 pupæ, 8 produced normal adults.

The experiments cited in Table III, with the exception of the lot of puparia eaten by a field mouse, show that the greater emergence percentage occurred when larvæ were placed upon grass sod. By this method sufficient moisture was supplied, and at the same time the movement of the larvæ to the roots of the grass protected the pupæ from excessive heat. In one lot 32 adults emerged from 35 pupæ, and in another, under similar conditions, 38 adults emerged from 42 pupæ.

It is also noted from other experiments that excessive moisture or dryness is less favorable for the metamorphosis.

EFFECT OF HEAT ON LARVÆ AND PUPÆ.

Doubtless numerous larvæ and pupæ are subjected to heat, in barren places, when dropping from work horses driven upon the roads. This may not be confined to the heat of the sun, for horses standing in stalls may drop larvæ which are placed with the manure in piles that generate heat. The results of some tests are given in Table IV.

TABLE IV.—*Effect of heat on larvæ and pupæ of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

Date subjected.	Stage.	Number.	Environment.	Period of time subjected.	Temperature experienced.			Number pupating.	Number adults emerged.	Per cent death.	Period, collection to emergence.	Temperature after heat test.		
					Max.	Min.	Mean.					Max.	Min.	Mean.
1915.					° *F.*	° *F.*	° *F.*				*Days.*	° *F.*	° *F.*	° *F.*
July 5	Larvæ	10	Glass jar with gauze cover, buried in manure pile.	6 hours			156.2			100				
Do	do	5	Buried in manure pile	15 minutes	152.6	150.8	151.7			100				
July 13 [1]	do	6	In sun, black loam	8 minutes	122.0	121.1	121.6	6	2		34–36	85	40	61.70
July 31	Pupæ	4	do	30 minutes			116.6	4	0	100				
Do	do	4	do	62 minutes			116.6	4	0	100				
Do	do	4	do	98 minutes			116.6	4	0	100				
Do	do	4	do	137 minutes			116.6	4	0	100				
July Check								5	4		38–39	85	40	62.45
Do	Pupæ	8	In sun on black loam	137 minutes			116.6	8	0	100				
Do								6	4		38–39	85	40	62.48
1916.														
July 3	Larvæ	3	In sun on black loam	8 minutes	125.6	120.2	122.9	1	0	100				
Do	do	3	do	10 minutes	125.6	120.2	122.9	0		100				
Do [2]	do	4	do	12 minutes	125.6	120.2	122.9	1		100				
July 7 [2]	do	3	do	5 minutes	131.0	125.6	128.3	3	2		24–25	85	40	64.92
Do	do	4	do	7 minutes	132.8	125.6	129.2	2	0					
Do	do	4	do	9 minutes	132.8	125.6	129.2	1	1					
Do	do	4	do	12 minutes	132.8	125.6	129.2	2	2					
Do	do	4	do	14 minutes	132.8	125.6	129.2	1	1		26	85	40	66 61
Do	do	4	do	17 minutes	133.7	125.6	129.7	2	1		26	85	40	66–61

[1] A fungus developed.
[2] Larvæ showed activity after subjection to heat.

Upon hard soil the larvæ are seldom observed to move more than a foot, and this sometimes requires 15 minutes. The tendency seems to be confined almost wholly to burrowing, and it is only when dropped on unsuitable places that they migrate. When exposed upon hard, barren soil to the heat of the sun during the summer it seems certain that only a few find protection and eventually produce adults. Certainly those not finding suitable protection from the sun's heat die within a short time. On black loam at a mean temperature of 122.9° F., 8 to 12 minute exposures caused 100 per cent mortality. Yet some larvæ seem to withstand even higher temperatures, for adults were produced after having been exposed from 5 to 17 minutes at a mean of 129° F. Pupæ, being unable to accommodate themselves by moving for protection, seem to be very susceptible to heat. Exposures of from 30 to 137 minutes at 116.6° F. were sufficient to render them inviable.

The heat generated in a manure pile produced greater mortality upon larvæ than ordinarily would be expected. Larvæ buried without protection at a mean temperature of 151.7° F. were dead within 15 minutes, having become soft and white.

EFFECT OF SUBMERGENCE ON LARVÆ AND PUPÆ.

Although, as shown in Table III, excess moisture seems to have had a destructive effect upon pupæ, the effect of submergence upon larvæ is not so great. Larvæ submerged 51 to 74 hours pupated and produced adults. (See Table V.) Larvæ submerged for 80 hours pupated, but failed to emerge when kept under favorable breeding conditions. While it is difficult to submerge pupæ, as they float and expose a portion of the posterior spiracles, three normal ones kept in water for 5 days failed to emerge. In view of the results in Table III, it is apparent that great mortality occurs among pupæ during wet seasons.

TABLE V.—*Effect of submergence on larvæ and pupæ of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

Date submerged.	Stage.	Number.	Period submerged.	Number pupated.	Adults emerged, (male.)	Larval longevity, including period of submergence.	Collection to emergence.	Temperature after period of submergence.		
								Max.	Min.	Mean.
1915.						*Days.*	*Days.*	°*F.*	°*F.*	°*F.*
July 5..	Larvæ...	6	51 hours.....	4	3	5	36	85	41	63.93
July 14..	do....	3	74 hours.....	2	1	.....	38	85	41	64.21
Do...	do....	3	20 days.....	0	.....	17–20	.....	85	41	62.95
July 24..	do....	5	14 days.....	0	.....	9–14	.....	80	40	58.14
July 2..	Pupæ...	3	5 days.....	0	.....	.....	.....	82	40	59.40
1916.										
June 7..	Larvæ...	9	7 days.....	0	.....	12	.....	76	43	64.83
Do...	do....	5	6 days.....	1	.....	8–12	.....	76	43	64.83
July 12..	do....	15	7½ days.....	.....	.....	8	.....	96	64	76.50
Do...	do....	5	80 hours.....	5	.....	4	.....	96	64	75.90
Do...	do....	5	5½ days.....	.....	.....	7	.....	96	64	76.50

Larvæ have been observed to remain alive during submergence for from 14 to 20 days; those submerged 6 and 7 days live for some few days after removal.

NATURAL CONTROL.

FUNGUS DEVELOPMENT.

Under conditions the same as those upon which adults were reared in Table II apparently two species of fungi developed upon living material. The first mentioned in Table VI occurred upon three larvæ, to one of which a particle of horse manure adhered. They were collected from the rectum of perspiring horses, and it appeared that the fungus developed from the manure and spread to the larvæ and pupæ. The larvæ giving promise of fungus development were placed in a clean tin pill box with three well-washed *G. haemorrhoidalis* larvæ, which had been exposed to the air at the anus of a horse for about 24 hours preceding the washing. The fungus developed upon all the larvæ and death ensued. This fungus was determined by Mrs. Flora W. Patterson, Mycologist of the Bureau of Plant Industry, as *Sporotrichum minutum*. This, with one exception, was the only lot in which fungi appeared on living larvæ. As this fungus had developed upon larvæ collected from perspiring horses, it seemed possible that such larvæ as were not washed might have developed a superficial growth. Later collections were made from work animals which were perspiring during the time of collection, and they were kept under similar conditions, but no fungus appeared. In collections of larvæ kept under normal rearing conditions, as given in Table VI, a fungus appeared on the pupa stages which apparently spread to other pupæ in the same lot. In some lots pupæ remained without becoming infected, but in others it even developed upon various parts of the tin boxes. The collections and rearing methods used in these experiments were not unlike those in which no fungus appeared, as new, clean, but unsterilized tin boxes were used in each breeding experiment, and sterilized forceps were used in handling. The soil or medium was different in the various boxes, but since these various conditions were also present in lots which developed no fungi, there appears to be no reason for attributing it to the type of soil or to the medium. Upon the pupæ it appeared within from 3 to 17 days after collection.

TABLE VI.—*Fungus development upon pupæ of Gastrophilus haemorrhoidalis in new tin boxes at Aberdeen, S. Dak., 1915–16.*

Larvæ from rectum.	Collection and environment.	Prepupal period.	Fungus appeared.	Pupal period.	Larvæ collected.	Larvæ pupated.	Number infected.		Adults emerged		Temperature collection to emergence.		
							Pupæ.	Larvæ.	Male.	Female.	Max.	Min.	Mean.
1915.		*Hours.*	1915.	*Days.*							°*F.*	°*F.*	°*F.*
June 11[1]	From perspiring horses	79–220	June 15	34–36	13	10	10	3	2	2	88	40	65.54
June 15	do	75	June 30	35–38	10	10	10	....	5	1	88	40	64.66
June 21	do	20–219	June 25	30–32	34	29	29	5	7	6	85	41	63.88
July 6	With fresh horse manure	6–25	July 13	34	5	3	3	....	1	....	85	41	63.85
Do	From perspiring horse	23	.....	.....	1	1	0	.....	.....	.....	.....	.....	.....
July 7	do	6–43	July 13	33–36	3	3	3	....	1	1	85	41	62.12
July 10	With moist loam	5–18	do	33–36	40	40	40	....	14	11	85	41	64.32
July 13	do	21–29	July 16	33–35	4	4	4	....	1	1	85	41	64.43
1916.			1916.										
May 17[2]	On blotting paper	22–32	May 29	.....	7	7	7	.....	.....	.....	.....	.....	.....
June 2[2]	do	20–39	June 14	.....	13	11	11	.....	.....	.....	.....	.....	.....
June 5	do	77–102	June 22	.....	2	2	2	....	0	0	76	42	59.14
Do.[2]	With moist sand	48–72	June 12	.....	8	7	7	.....	.....	.....	.....	.....	.....
June 9[2]	do	22–70	June 17	.....	10	10	10	.....	.....	.....	.....	.....	.....
June 24	do	4–122	June 29	21–25	62	59	59	....	24	15	96	48	74.67
June 26[2]	do	19–166	July 1	.....	20	17	16	.....	.....	.....	.....	.....	.....
June 27	do	22–190	July 3	21–29	15	13	12	....	4	6	96	56	75.73
July 1	do	3–6½	July 6	20	4	4	4	....	....	1	96	58	77.07
July 18[2]	With moist sand	21–67	July 25	.....	14	12	2	.....	.....	.....	.....	.....	.....
July 24	do	21–31	July 28	29	19	18	18	....	5	3	98	51	70.19

[1] Determined by Mrs. Flora W. Patterson as *Sporotrichum minutum*.
[2] Determined by Dr. A. T. Speare.

Except the collection on May 17, 1916, larvæ were not washed.

Several lots were sent to Dr. A. T. Speare, Mycoentomologist of the Bureau of Entomology, who made cultures and determined the characters showing that all the infestations were of one species and were not Sporotrichum.

According to Dr. Speare about 50 per cent of the pupæ sent to him produced adults. He reported that the fungus seemed to be restricted in its development to the chitinous wall of the puparium, and that death, if caused by the fungus, must have been brought about in some unusual way, as, for example, by closing the spiracles. However, the fungus seems to develop best at the rings of the segments and is seldom observed upon the posterior spiracles.

In Table IV it will be observed that a fungus appeared upon pupæ which had been subjected to heat tests, and this was apparently the same as has been observed in other experiments. A comparison of results and mortalities due to the fungi indicates that there is little hope of controlling the Gastrophilus by encouraging natural development of the fungus. Eighteen lots containing 283 larvæ produced 259 pupæ, of which 247 became infected with fungus in rearing experiments. Twelve of the lots, containing 194 pupæ, were retained for observations on mortality. Of these, 64 males and 47 females emerged as normal adults, giving 57 per cent emergence. The adults

possessed a normal longevity as compared with others in rearing experiments.

The above percentage of mortality is based upon those experiments in which the fungus occurred. As there seems to be no reason for attributing the fungus to soil or media it is well to base this percentage upon all experiments in tin boxes and where pupæ were in close proximity. In Tables II and VI, 630 larvæ produced 578 pupæ. Of these 247, or approximately 43 per cent, developed a fungus. Of the ones kept under observation 57 per cent emerged, so that only 43 per cent of the infected pupæ were rendered inviable; 43 per cent of 43 per cent would approximate 18.5 per cent, or the percentage of loss in rearing experiments where numbers were kept in close proximity, which probably allowed the infection to spread over individual lots.

In Table III it is shown that no infected pupæ were found, and should a fungus develop in such conditions the single location of pupæ would prevent its spreading. This fungus has never been observed upon normal *G. intestinalis* or *G. nasalis*, though with dead larvæ of any Gastrophilus a long growth of fungus quite different from that met upon living *G. haemorrhoidalis* pupæ is frequently found.

PREDATORS AND PARASITES.

The dropping of larvæ under varying conditions and in locations where they do not pupate in close proximity renders the situation such that very little could be expected of predators and parasites in control. In rearing experiments some field mice devoured pupæ on grass sod, but even though they feed upon these in nature it is not likely that a great many are devoured. Chickens probably do not feed upon many larvæ when they drop, though a single hen has been known to devour about 40 dead *G. intestinalis* removed from a horse by a carbon disulphid treatment, and without any noticeable ill effects upon the chicken.

Desiring to know if the widely distributed *Nasonia brevicornis*, which parasitizes various species of dipterous pupæ, could be reared upon *G. haemorrhoidalis* pupæ, repeated efforts were made, but without success. The indications are that the flycatchers feed very little upon Gastrophilus adults. On account of the danger in shooting such birds in pastures very few examinations of stomachs have been made.

LIFE-HISTORY NOTES.

ADULT LONGEVITY.

The life of adults appeared so short at the beginning of experiments that it was attributed to abnormal conditions, but various cages and environments did not materially increase the periods. A total of

254 males and 184 females were used in the experiments. All of these emerged normally from reared material. While some adults died on the first and second days the maximum longevity was 7 days. The greater periods were always obtained when the cages were kept out of the bright sunlight and provided with more or less foliage to prevent adults from battering themselves against the sides of the cage. Twenty-seven males and 15 females liberated in the insectary (9 by 12 by 7 feet) died within 1 to 3 days and were found dead at a sunny exposure with the wings battered. Cages admitting a great amount of light and without foliage yielded similar periods of longevity.

Adults in screen cages 18 by 18 by 18 inches or in a parasite-rearing box (covered on two sides with glass and arm holes in the ends) usually died within 3 days. This longevity was slightly extended when green twigs were frequently replenished.

The longest periods were obtained in wooden boxes 4 by 4 by 6 inches half filled with moist soil and provided with a green twig and a glass cover. This lessened adult activity, and from the 51 longevity experiments it was observed that the greater periods were always accompanied with the least activity, while the converse was also true. These wooden boxes placed in the shade admitted enough light to permit of activity and flies were often observed to fly about with the head near the glass and would alight on the green twigs and rest. The usual longevity under such conditions ranged from 3 to 6 days. Some adults captured in nature were kept under similar conditions and lived from 3 to 5 days.

Various flowers were supplied as food for the adults, but in no case was feeding observed. Sweepings were also made from flowers blooming in pastures and from alfalfa in bloom, but adults were never captured under such conditions.

ADULT HABITS.

Adult flies in cages copulate most frequently about noon, the duration of the act ranging from 3 and 4 to 15 minutes. During the act the flies usually remain quiet, except for the distinct abdominal movements of the male. The male usually breaks from the female, leaving her at the place of copulation, but within a few minutes may be observed to return. One pair has been observed to copulate as many as four times within an hour. Males will mate with a freshly emerged female before her wings are dry, properly unfolded, or the body of a normal color. In nature the one object of the male seems to be copulation, and that of the female oviposition. Buzzing in midair about the horse the male may be easily caught with the hand. A female is only observed buzzing at a standstill in midair when

a horse is grazing or otherwise protected from ovipositions. She usually comes from a distance and strikes at the lips. Her quick flight seems to be distinguished by the male, who attempts to mount her before she oviposits, but the momentum of the two usually carries the couple to some distant place so quickly that one can not tell whether copulation actually takes place upon the wing or whether they fall to the ground. At any rate, they fly for some distance. Apparently the sexes always meet at the horse, the males awaiting the approach of the females. At times the male encounters an adult female of *G. intestinalis* about the horse, and these two may be observed to fall upon the grass at the feet of the horse, usually separating within a few seconds.

PREOVIPOSITION PERIOD AND OVIPOSITIONS.

Just how soon after emergence copulation takes place is not definitely known, but it is certainly less than 18 hours. Adults emerging during the night copulate by noon of the following day and will oviposit during that afternoon. They will not oviposit in captivity. On five occasions in which flies emerged normally during the night, males and females were kept in a box with glass sides and with green foliage. By noon in each case some were observed to copulate and when liberated in the afternoon would oviposit. Their wings were colored with red ink, and when captured they could be identified easily. Under favorable conditions ovipositions took place as soon as adults were liberated, usually about 3 hours after copulation. After a lapse of a few minutes they were never to be collected about the same bunch of horses, which is probably due to the migration of adults and to the movements of the various horses upon which they oviposit.

A determination of the egg-laying period is important in that it shows the value of destroying adults at different times during this stage, but with such short preoviposition and longevity periods and the inability of flies to feed, the indication is that the flies oviposit throughout their existence. Dissections of females reared to adults indicate that they develop from 134 to 167 eggs, the usual number possibly being near 150.

Unlike *G. intestinalis*, which may stand in midair and consecutively deposit 15 or 20 eggs at one time, often placing two or more upon one hair, *G. haemorrhoidalis* deposits but one at a time and only one upon a hair. It leaves the animal for about one-half minute or longer after ovipositing, but not for so long a time as does *G. nasalis*. It never oviposits upon any other portion except the lips, preferably the portions moistened by saliva. The stalk portion of the egg is inserted in the pore of the skin at varying depths, but

the stalk has never been observed to be inserted for its full length. Often it extends to such a slight depth that after a few days the egg may be found lying lengthwise upon the lips, yet firmly attached to the hair. The color, a jet black, so conceals the attachment to the transparent hair that it appears that the hair extends through the center of the stalk portion and through a portion of the side of the egg. The extreme point, however, shows a folding about the hair which may be attributed to the pressure when it is inserted in the pore of the skin. Above the stalk portion the hair is attached to the side of the chamber containing the larva in a similar manner to the attachment of other Gastrophilus eggs upon the hair.

INCUBATION AND INGRESS OF LARVÆ.

Having observed eggs upon both moist and dry portions of the lips of horses, large numbers in various stages of incubation were removed and placed in tubes for observation. About 100 were kept in a test tube, with a moist cotton stopper, at the air temperature of a living room. While a variation in color was at first observed, ranging from a black to a reddish color, after a few days the majority were of a reddish brown. Some were placed upon a slide and moistened, then by the use of two dissecting needles dead larvæ were removed. No larvæ had hatched of their own accord, but emerged when subjected to moisture and friction. In similar tubes which were kept dry three lots of eggs varying in color were observed and not a single larva hatched.

Examinations of the inside of horses' lips revealed numerous holes accompanied by much soreness which appeared as though the young larvæ hatched and had burrowed through the lips. Upon dissections in post-mortem examinations it was disclosed that the injury was caused by "wild barley" or "foxtail grass." This grass was determined by the Bureau of Plant Industry as *Hordeum jubatum*. Its injuries are more noticeable upon lips of livery horses when fed hay containing this grass, as pastured animals avoid eating it and the injury is less noticeable. It is worthy of note that this grass, in addition to its injury upon lips of horses, serves as a winter host of the black rust which is so destructive to wheat in the Dakotas.

On August 24, 1915, a suckling colt, its mother (a crippled horse) and another horse were carefully freed of eggs. Twenty-four hours later a diagram was made showing the exact location of each egg deposited during this time. Upon the following three days it was too cloudy for other adults to oviposit, so the horses were not kept in a barn to prevent further ovipositions, but were left to graze in the pasture. This allowed ample time for development of the embryo and of a distinguishing brownish-red color which greatly aided in keeping track of the eggs.

Upon the suckling colt the first egg disappeared upon the ninth day; the eleventh day, two; the thirteenth, five; and the fourteenth, six. Five other eggs about 1 inch from the mucous membrane and upon the dry portions yielded dead larvæ when examined.

Upon the lips of the cripple horse and within 1 inch of the mucous membrane 15 eggs were deposited. The first 6 eggs disappeared upon the seventh day from near the corners of the mouth. The last egg disappeared upon the eighteenth day.

The normal horse in grazing received 14 eggs within 1 inch from the mucous membrane. Upon the sixth day 10 eggs disappeared from near the corners of the mouth, which was probably five days from deposition. The other 4 disappeared during the following three days.

The striking feature of the above three cases is that those eggs deposited where they received most moisture and friction were the first to disappear. Prior to disappearance, the color changes, being first brownish, then a brownish red, finally with a whitish tip, thus clearly indicating embryonic development. It is also clearly seen that the amount of grazing affects the incubation, as the normal horse grazed practically the whole time, the cripple only at times, while the suckling colt was not observed to graze. There were no indications that the larvæ burrowed into the lips, and as well-incubated eggs have produced larvæ under moisture and friction when removed, it is certain that the method of ingress of larvæ into the host is not unlike that of *G. intestinalis*. It is true that eggshells were never found attached to the hairs after the larvæ had emerged, but it is believed the moisture and friction are sufficient to remove these after the larvæ leave the eggs and enter with the food.

Incubation records are not confined to the above three cases. Upon August 24, 1915, one other animal was freed of eggs and allowed to receive depositions during 24 hours. Upon the moist portions of the lips 17 eggs were found, while 6 were deposited upon the dry portions 1 inch from the mucous membranes. Separate notes give a comparative idea of the incubation. Upon the sixth day, probably 5 days from deposition, 4 eggs disappeared from the moist portions and others disappeared the following day. Upon the dry portions all were present upon the twelfth day. Three of these when removed contained dead forms and the other 3 disappeared from the eighteenth to the twenty-third day.

The day of oviposition in the above cases was favorably followed by three cloudy days, which prevented other ovipositions. The development of the embryo in eggs upon moist portions was quite in contrast to those upon the dry portions, showing clearly the necessity of moisture and friction. Such observations indicated that those

eggs upon the moist portions incubated in from 5 days to a slightly longer period.

September 9 was preceded by two unfavorable days for oviposition and was itself very favorable, but was followed by rain and cloudy weather until September 15. At this time black eggs were found upon the dry portions of the lips, while upon the moist portions the eggs were reddish with whitish tips. Due to the scarcity of adults, the eggs were not plentiful at this time, and a few days later one only could be found, upon the dry portions of the lips.

Due to the comparatively long period during which the eggs remain attached upon the dry portions of the lips of horses, which is particularly due to the protection of the thick, coarse hairs surrounding them, it is believed that one could be misled easily as to the most favorable places of deposition of the adults.

GASTROPHILUS NASALIS (Linnaeus).

SYNONYMY.

Oestrus nasalis Linnaeus, 1761.
Oestrus veterinus Clark, 1797.
Oestrus salutiferus Clark, 1815.
Oestrus clarkii Leach, 1817.
Gastrus nasalis Meigen, 1824.
Oestrus duodenalis Schwab, 1840.
Gastrophilus nasalis Schiner, 1861.

OVIPOSITIONS AND LONGEVITY.

The female *Gastrophilus nasalis* often appears from the grass about the fore legs of a grazing animal, strikes under the jaws, remains a few seconds, and during that time deposits an egg about midway upon the hair. The adult then leaves, completely disappearing in the distance, but within a minute or two a similar oviposition may occur, except that the adult approaches from a distance. The presence of a person about the head of an animal does not interfere with egg deposition, and the fly may be caught with the hand when it alights upon the hairs underneath the jaws. It may also be observed to deposit upon the fore legs or the flanks. Dissections of the abdomen of reared females show that they are capable of depositing from 480 to 518 eggs. The attachment of these, as may be seen by referring to figure 3, *c*, extends to almost the entire length of the egg, and being attached about midway upon the hair, numbers are concealed unless the hair is brushed aside in making examinations. Often eggs may be observed near the end of the hairs, but this usually occurs after great numbers have been deposited. Then it is possible to find two or more eggs upon one hair. As yet the method of ingress of the larvæ has not been determined. Dr. C. H. T. Townsend thinks that the larvæ burrow through into the mouth

and are swallowed. One author believes that a horse in eating will rub the jaws upon the manger, which hatches the eggs, and that they are taken into the mouth with the food. The fact that some eggs are deposited upon the fore legs and portions accessible to the mouth indicates that the ingress of larvæ may be similar to that of *G. intestinalis*.

Longevity in this species seems to be increased over that of *G. haemorrhoidalis*, as one reared adult kept under conditions similar to those of the nose fly lived for 12 days.

LARVA AND PUPA STAGES.

Coincidentally with the appearance of *G. haemorrhoidalis* at the anus of horses, the larvæ of *G. nasalis* occasionally may be observed to pass normally from horses and be found in their droppings. This normally occurs when larvæ become fully developed and is often attributed by farmers to "a destructive effect of grass upon the bots."

These larvæ seldom migrate a great distance, and apparently only burrow under the droppings for protection. Larvæ which dropped normally pupated in from 1½ to 2 days, though the prepupal periods in some cases in which larvæ were removed in autopsies and cited in Table VII extended for 7 days. It was observed that the short pupal periods were preceded by long prepupal ones, and that larvæ pupating within 2 days after dropping emerged in from 42 to 45 days. At Victoria, Tex., Mr. J. D. Mitchell collected a larva under manure, which pupated October 6, 1914, and emerged 20 days later. To rear larvæ collected in autopsies is a difficult task, even though they are well developed and appear normal, but during the late summer a small percentage may be reared if they are collected from horses immediately after death. The larvæ removed from dead animals are capable of remaining alive and active for some time, some having been kept as long as 25 days. Some larvæ have been observed to live submerged in water for 12 days.

TABLE VII.—*Pupal periods of Gastrophilus nasalis, Aberdeen, S. Dak., 1915–16.*

Larvæ collected.	Location.	Number larvæ.	Breeding environment.	Number pupated.	Range of pupal period.	Number emerged.		Longevity larvæ not pupating.	Temperatures.		
						Male.	Female.		Maximum.	Minimum.	Mean.
1915.					*Days.*			*Days.*	°*F.*	°*F.*	°*F.*
June 4	Fresh dropping	1	With horse manure.	1	42	1	.....	.....	88	35	65.30
1916.											
May 29	.....do.....	2	Clean tin box; moist sand.	2	44–45	1	1	.....	94	42	67.93
June 12	Dropped from treatment.	4	.....do.....	1	31	1	.....	7	94	42	[1]68.98
July 10	Duodenum	19	Dry paper in tin box.	3	25–33	1	2	3–15	98	41	72.77
Aug. 11	Stomach	18	Moist sand	3	48	1	.....	3–8	98	28	60.26
11	Duodenum	18	.....do.....	3	56	1	1	11	95	28	59.97

[1] Horse treated with carbon disulphid.

GASTROPHILUS INTESTINALIS (DeGeer).

SYNONYMY.

Oestrus bovis Linnaeus, 1761.
Oestrus intestinalis De Geer, 1776.
Oestrus equi Clark, 1797.
Gastrophilus equi Leach, 1817.
Gastrus equi Meigen, 1824.
Oestrus gastricus major Schwab, 1840.

OVIPOSITIONS AND LONGEVITY.

The universal distribution of the common bot-fly, the familiarity of innumerable persons with its oviposition habits, and the numerous publications dealing more particularly with ovipositions and ingress of the larvæ into the host since Bracy Clark (1797), leave little to be desired. It is probable that there is no other insect whose eggs come so directly under the observation of farmers as does the common bot-fly. The common names of this Gastrophilus vary with the locality, but farmers are usually aware of the fact that this insect produces the bots in horses.

Some authors contend that the eggs are deposited upon those places most accessible to the horse's mouth, while others hold that the fly will deposit upon any portion where it is not disturbed. It has always been observed that these flies give preference to the forelegs, and, after these have become well covered with eggs, depositions occur at other points where the fly is not disturbed by the horse's tail. Very few eggs are deposited upon the hind legs or upon the backs of the animals, but when adult flies are in numbers the mane may become heavily infested, especially near the shoulder. Large numbers of eggs may be found upon the sides of the animals, and these are concentrated at points accessible to the mouth, as in cases of depositions upon the inside of the forelegs. It seems that the fly oviposits on the forelegs instinctively, and, after the legs become heavily infested, adults may be observed to deposit one or two eggs on them and then seek other portions of the body. At times two or more eggs may be found upon a single hair on the inside of the forelegs, but seldom has this been noted upon other portions. However, the length of the mane often permits adults to deposit large numbers upon a single hair. With the exception of the forelegs, the sides below and to the rear of the shoulder blades probably harbor most eggs.

The longevity of 14 reared adults in 9 tests, in which the flies were kept under conditions similar to those employed in rearing *G. hæmorrhoidalis* varied from 7 to 21 days. The longer periods occurred during early fall, when lower temperatures were experienced. These adults, like those of other species of Gastrophilus, were never

observed feeding upon flowers, but green twigs were favorable resting places in rearing cages.

A female taken while ovipositing was placed within a tube containing a male, and they were observed to copulate for 5 minutes.

Dissections of 5 females showed the following egg capacity: Maximum, 770; minimum, 397; average, 541.

INCUBATION AND INGRESS OF LARVÆ.

While making observations in pastures, on four occasions large numbers of eggs were collected which had been deposited upon the author's horse. The eggs were kept in tubes at air temperatures of a living room and none hatched without friction and moisture. By placing the infested hair upon a microscope slide and moistening it the larvæ were most easily removed by rubbing the lot with a dissecting needle. In such tests the eggs remained attached to the hair, while the operculum was removed, allowing the larva to emerge. Very good results were also obtained by rubbing a moistened finger over the lot. When eggs were less than 7 days old it was found difficult to obtain living larvæ, though at 9 and 11 days active larvæ were removed. When they were slightly older than 11 days they emerged without difficulty when attended by moisture and friction, and one living larva was found as late as the forty-eighth day. This seemed to be an exception, as in the other lots all were dead after 40 days. In general, all experiments tended to confirm those of Osborn. According to Guyot, with various lots placed in paper bags and kept in a pasteboard box at room temperatures, some emerged without moisture and friction. On December 28, 1900, Guyot obtained quite agile larvæ as late as 96 days after collection of the eggs. In another case, with eggs collected on October 6, he succeeded in obtaining larvæ from January 7 to 13 following, a period of 92 to 98 days. Due to this fact, Guyot concludes that the larvæ are capable of withstanding comparatively low temperatures after the eggs have been removed from the host. From eggs collected on horses in the open, active larvæ were removed as late as December 1.

LARVA STAGES.

The attachment of young larvæ frequently occurs in almost any part of the stomach, but, as has been previously stated, they are found as fourth-stage larvæ upon the mucosa of the stomach, more especially on the left sac. If living larvæ are removed from an animal during a post-mortem examination a great tendency for reattachment will be observed. During such examinations they have been frequently separated into lots according to species, and in a short

time they would attach to a piece of paper or stomach section or even to one another. This is only a temporary attachment, however, and apparently no attempt at feeding takes place.

The studies of Brauer, Numan, and Guyot indicate that the larvæ molt during their development and that there are at least three stages. No experiments have been reported as to the exact time that larvæ remain within the body of the horse, although apparently they spend about 10 months in this parasitic stage. On some occasions, as will be observed in Table I, well-developed larvæ were disclosed on post-mortem examinations in early fall. The indications are that some larvæ are not sufficiently developed to pass out in time to produce adults and that they succumb to low temperatures. There are various factors that apparently tend to influence the extension of larval periods. When gross infestations occur the development is markedly slower than in those horses containing only a few larvæ. Laxative foods have a greater tendency to discharge well-developed larvæ than foods of a non-laxative nature, as is observed in comparing autopsies of livery and pastured animals. Since there is such a wide range of variation in the ages of larvæ within the eggs at which they are capable of being ingested it is possible that this may tend to prolong the period during which the last-stage larvæ drop.

SUBMERGENCE OF LARVÆ.

Last-stage larvæ removed from horses immediately after death remained alive and active from 21 to 33 days when submerged in water, but when submerged for only 6 days they would not attempt pupation. These periods are considerably decreased if larvæ are not removed shortly after the death of the animal.

PUPA PERIODS.

The larvæ drop naturally with manure, burrow only enough for protection, and normally pupate within a day or two. The periods of dropping extend over a long time and very few larvæ are found in droppings. It is a difficult matter to rear larvæ taken in post-mortem examinations, and this is best undertaken in the late summer or early autumn, when the greatest number of larvæ are fully developed. With such larvæ, used in the experiments, the pupa periods have been observed to vary from 27 to 43 days, with an average of 38 days.

EFFECT OF DEATH OF HOST UPON GASTROPHILUS LARVÆ.

The resistance of larvæ and the death of horses from infectious diseases naturally suggest the fate of larvæ during the period when they normally drop. In experiments larvæ were not kept with the animals during the decay, but were removed in autopsies, separated

according to species, and placed under favorable rearing conditions. It is evident that larvæ within the stomach and duodenum are not capable of withstanding the internal processes which accompany the decomposition of animal tissues, especially during warm periods. There is excessive gas formation with the breaking down of the tissues, and the larvæ apparently become asphyxiated, since they are found bloated and when crushed become flat. During cool periods larvæ are affected very little for a number of hours, and in stated cases as long as 30 and 48 hours after death of the host larvæ have been reared to adults. Low temperatures hold back that period of decay in the carcass which normally would cause the death of larvæ.

From post-mortem examinations, as will be seen in Table I, *G. haemorrhoidalis* larvæ are seldom found in the rectum. In all probability they drop shortly after death, and during the normal period of dropping are capable of producing adults.

CONTROL STUDIES.

REMOVAL OF G. HAEMORRHOIDALIS LARVÆ FROM RECTUM.

The effectiveness of the extraction of Hypoderma larvæ as advocated by various authors suggests a mechanical removal of *G. haemorrhoidalis* larvæ. While they appear at the margin of the anus daily, studies show that they remain visibly attached from 40 to 71 hours. This would necessitate much work during a busy season with farmers, but extractions at feeding time would greatly reduce the number in work animals. In practice this periodical detaching caused much discomfort and soreness about the anus.

The attachment of clusters of larvæ within the rectum and the recommendation of tobacco decoctions, by the Bureau of Animal Industry (1911), for larvæ lodged in the rectums of horses, indicated the need of information as to the effect, on this species of Gastrophilus, of substances used as enemas. This necessarily required a detailed study of the effects of various substances upon larvæ, and these are reported in Table VIII.

TABLE VIII.—*Treatment of Gastrophilus haemorrhoidalis larvæ from rectums of horses, with contact insecticides, Aberdeen, S. Dak., 1915–16.*

Number of larvæ.	Contact insecticides.	Exposure.	Immediate effects on larvæ.	Larvæ died.	Larval longevity after treatment.	Number pupating.	Pre-pupa period.	Pupa period.	Emergence.	
									Male.	Female.
					Days.		*Days.*	*Days.*		
5	Tincture quassia	1 hour 10 minutes	Apparently none	0		5	1–5	35–36	1	2
5	Essence ginger	10 minutes	Hooks concealed	0		5	1–2	33 36	2	2
5	Saturated solution borax [1]	5 hours	do	All.						
5	10 per cent carbolic acid	5 hours 15 minutes	Contracted	All.						
5	Tar soap, soft	4 minutes	Activity increased	All.						
5	Tar soap, soft, and resin	do	do	All.						
5	Saturated solution boric acid	26 minutes	Contracted	All.						
5	do	10 minutes	None	0		5	1–2	33–34	2	2
5	Beta naphthol, chloroform, soap, and water	40 minutes	Inactive	All.						
2	Hellebore and water	2 days		1	12	1	6	44		1
2	Soft tar soap, water, and resin	2¾ days		All.						
4	3 per cent carbolic acid	5 minutes	Contracted	All.	7					
5	10 per cent carbolic acid	Posterior end dipped	Inactive	All.						
5	do	2 minutes	do	All.						
10	Nicotine sulphate	do	do	All.						
6	Nitrobenzine gas	21 hours	None	0		6	2–4	28–29	2	
5	do	1 minute	do	All.	1–6					
6	Cresol, 2.7 per cent phenols [2]	do	do	All.						
5	Cresol, 1.35 per cent phenols [2]	do		All.	6					
5	Nitrobenzine	2 minutes				5	1–3	26–28	2	1
4	Cresol, 1.35 per cent phenols [2]	Posterior end dipped	None			4	2–3	27–29	2	1
6	Cresol, 0.45 per cent phenols [2]	5 minutes	do			6	3–5		0	0
3	do	10 minutes	do			3	1–3	26–28	1	2
3	do	15 minutes	do			3	1–3	26–28	1	2
5	do	20 minutes			6	4	1–3	26		1
6	Nitrobenzine	4 hours	Inactive	All.	4					
5	do	1 minute	None	All.	7					
5	do	2 minutes	do	All.	7					
5	do	3 minutes	do	All.	7					
3	16⅔ per cent carbolic acid	do	Contracted	All.						
4	do	4 minutes	do	All.						
3	8⅓ per cent carbolic acid	2 minutes	do	All.	2					
4	do	4 minutes	do	All.	2					
3	4⅙ per cent carbolic acid	2 minutes	Soft	All.	4					
4	do	4 minutes	do	All.	4					
5	6⅔ per cent nicotine sulphate	1 minute	None	All.	2–4					
5	do	2 minutes	do	All.	2–4					
5	do	3 minutes	do	All.	2–4					
5	3⅓ per cent nicotine sulphate	1 minute	do	All.	2–9					
5	do	2 minutes	do	All.	2–4					

5	3½ per cent nicotine sulphate	3 minutes	do	All.	2-9					
5	1⅝ per cent nicotine sulphate	1 minute	do	All.	2-9					
5	do	2 minutes	do	All.	4-13					
5	do	3 minutes	do	All.	2-9					
4	do	5 minutes	do	All.	2-7					
4	do	12 minutes	do	All.	4-9					
5	do	20 minutes		All.	4-9					

[1] No effect from 10-minute submergence.

[2] Cresol suspended in resin soap.

Some of the tænicides and larvicides which have been successfully used upon insects, as well as soapy enemas, were tested upon detached larvæ in tin boxes. As with other Gastrophilus larvæ, remarkable resistance was noted. It will be observed that negative results were obtained by using the common tænicides, that soap solutions seemed more effective, and that nicotine sulphate gave good results.

LARVAL TREATMENTS.

Experimenters have been impressed with the resistance of Gastrophilus larvæ to various contact substances, and it is practically agreed that any contact substance capable of killing the larva would seriously injure the stomach membranes of the horse. The internal method for use must necessarily be in the form of a fumigant. The use of carbon disulphid internally, as brought out by Perroncito and Bosso, has been tried and indorsed by many veterinarians. A list of indorsements from many countries can be found in articles dealing with this subject. Originally the disulphid was administered in 12-gram capsules surrounded by aloes, the whole contained in 48-gram gelatine capsules. In the hands of various workers it has been subjected to modifications, but each reports that large numbers of larvæ pass as a result of the treatment, and some remark upon the beneficial effects of the removal of larvæ upon the animal.

The Bureau of Animal Industry, after employing this treatment upon a number of horses, recommends the following procedure:

> The day preceding the treatment a small amount of hay and a moderate amount of oats is given in the morning; in the evening food is withheld and a purgative given—Barbados aloes 1 ounce, or raw linseed oil 1 pint. The day of the treatment, at 6 o'clock in the morning, give 3 drams of carbon disulphid in a gelatin capsule; at 7 o'clock repeat the dose in the same manner; and at 8 o'clock give the third and last dose, making in all 9 drams of carbon disulphid in three gelatin capsules.
>
> The above treatment is for the adult horse. For a yearling colt half the quantity of carbon disulphid used for a mature horse will give the desired results. If properly administered the gelatin capsule reaches the stomach intact, but soon dissolves and the carbon disulphid rapidly evaporates, suffocating all bot larvæ and other parasites with which it comes in contact, but not injuring the horse. Worms are quite often expelled as well.

The Bureau of Animal Industry calls attention to the fact that the so-called 4-dram capsules hold about 3 drams of carbon disulphid.

Desiring to know the periods of time required to kill the larvæ in the treatments, a number of experiments have been conducted in fumigating stomach sections to which larvæ were attached. Only larvæ from those animals that could be secured shortly after the death of the hosts were used, and the sections with larvæ in situ were placed in wooden boxes tightly covered with glass after the box was well

moistened. The sections came from both the stomach and duodenum, and the tests include all three species of Gastrophilus. After the short periods of fumigation, which were ineffective with last-stage larvæ, it was observed that the larvæ lived for some days. At the end of fumigation tests it was impossible to determine the viability of larvæ except by observing them for a number of days. As will be seen in Table IX, chloroform was not wholly effective at 4 hours, but at a later date larvæ were killed with carbon disulphid within 3 hours. In no case did larvæ live after subjection to $3\frac{1}{2}$ hours of carbon disulphid. These gases were liberated from absorbent cotton in the corner of the box, and no larvæ came in direct contact with the liquid, as would probably be the case within the stomach. The carbon disulphid, being soluble in water, evidently reaches all portions of the stomach, either as a gas or in solution.

TABLE IX.—*Fumigations of horse stomach and duodenum sections with Gastrophilus larvæ in situ, Aberdeen, S. Dak., 1916.*

Post mortem and fumigation.	Species and number attached.	Exposure.	Fumigant.	Status at end of fumigation.	Mortality.	Longevity after fumigation.	Temperature since autopsy.			Remarks.
							Maximum.	Minimum.	Mean.	
1916.						*Days.*	° *F.*	° *F.*	° *F.*	
May 20	5 G. intestinalis	1 hour	Carbon disulphid	Attached and active	All alive	19–44	94	42	61.34	Reattached to one another.
Do	10 G. intestinalis	1½ hours	do	do	do	4–33	82	42	59.39	Detached after fumigation.
Do	17 G. intestinalis	do	do	do	do	9–28	82	42	59.28	Attached 40 hours.
Do	5 G. intestinalis	1 hour	Chloroform	do	do	10–35	82	42	59.39	
Do	7 G. intestinalis	1½ hours	do	do	do	4–42	94	42	60.54	Detached themselves after fumigation.
Do	21 G. intestinalis	do	do	do	do	16–44	94	42	61.34	Attached 40 hours after fumigation.
Do	2 G. nasalis	do	do	do	1 dead	0–9	79	42	58.50	One reattached to paper in breeding box.
Do	5 G. intestinalis	1 hour	Benzine	do	All alive	16–33	82	42	59.39	
Do	9 G. intestinalis	1½ hours	do	do	do	19–33	82	42	59.39	Detached themselves after fumigation.
Do	7 G. intestinalis	do	do	do	do	17–30	82	42	59.03	Attached 40 hours after fumigation.
Do	1 G. haemorrhoidalis	do	do	do	Alive	16	82	42	59.53	Detached after fumigation.
May 29	6 G. intestinalis	4 hours	Carbon disulphid	do	All dead					Attached 26 hours after fumigation, bloated.
Do	19 G. intestinalis	do	do	Detached and inactive	do					Bloated less than larvæ remaining attached.
Do	5 G. haemorrhoidalis	do	do	do	do					Did not bloat.
Do	3 G. haemorrhoidalis	do	Chloroform	do	All alive	16–21	82	43	59.48	
Do	3 G. intestinalis	do	do	do	do	16–21	82	43	59.48	
Do	20 G. intestinalis	do	do	Attached and inactive	do	19–24	82	43	59.65	Attached to string in breeding box.
Do	1 G. haemorrhoidalis	do	do	do	Alive	21	82	43	59.48	
June 8	do	3 hours	Carbon disulphid	Detached and inactive	Dead					Section of duodenum.
Do	11 G. nasalis	do	do	2 attached, all inactive	do					Do.
Do	15 G. intestinalis	do	do	do	do					Bloated few days after fumigation.
Do	4 G. haemorrhoidalis	do	do	All inactive, 1 attached	do					
July 11	19 G. intestinalis	1 hour	do	Detached and inactive	Some alive	3–13	96	58	74.90	Fungus developed on dead larvæ.
Do	1 G. nasalis	do	do	do	Alive	8	96	60	76.87	Do.
Do	20 G. intestinalis	2 hours	do	do	Some alive	3–13	96	58	74.90	Do.
Do	do	3 hours	do	do	Dead (?)					Kept 13 days; 1 appeared alive tenth day.
Do	40 G. intestinalis	3½ hours	do	do	All dead					No life whatever.
July 24	406 G. intestinalis	do	do	do	do					12 detached first 12 minutes.
Do	111 G. nasalis	do	do	do	do					In duodenum, 20 detached first 12 minutes.
Sept. 16	37 small Gastrophilus	2 hours	do	All inactive and some detached.	do					Appeared dead at 40 minutes' exposure.

Do	2 Gastrophilus	do	do	Active when handled	Alive	11	80	28	53.23	Larvæ detached at 40 minutes' exposure.
Do	31 small Gastrophilus	do	do	All inactive and some detached.	All dead					In duodenum, appeared dead in 40 minutes.
Sept. 18	19 small Gastrophilus	1 hour	do	All inactive and 7 attached.	do					
Do	3 G. intestinalis	do	do	Inactive and detached.	Alive	9	80	32	55.83	
Do	46 small Gastrophilus	do	do	All inactive and 21 attached.	All dead					Section of duodenum.
Dec. 9	50 small Gastrophilus	45 minutes	do	Inactive and attached.	do					Fumigation at Dallas, Tex.

[1] Two larvæ pupated 13 and 18 days after fumigation but did not emerge.

Except as otherwise indicated in "Remarks," larvæ were taken with stomach section.

The *G. intestinalis* are the most resistant of the Gastrophilus to treatments, but these, being found in the stomach, are in the most favorable place for treatment. No immediate effects of the gas upon last-stage Gastrophilus larvæ are observed, as they remain motionless for some time. Finally they contract so as to conceal the hooks of attachment and then drop from the stomach section. This sometimes occurs within 30 minutes after the fumigation begins, but most often it is after 1 or 2 hours. Occasionally the contraction is not so great and larvæ remain attached but drop at the slightest touch. A number of observations were made upon animals treated by local veterinarians. During the spring and early summer records were kept on 23 of these horses, which were treated when they contained only last-stage larvæ. The treatment was given as recommended by the Bureau of Animal Industry. Within 36 to 48 hours the first bots appear in the fæces, though if the physic acts well they may be found after 24 hours. The writer observed bots to pass for a period of 5 days, beginning about 36 hours after the treatment. With the first droppings a few living larvæ may be found which detached from the stomach before the treatment, and in one case *G. nasalis* was reared from such larvæ. *G. haemorrhoidalis* may appear at the anus as usual if this treatment is given in the spring, as by this time numbers have previously migrated to the rectum.

While Table IX shows that carbon disulphid gas is capable of killing last-stage larvæ within 3½ hours, the ideal time for treatment of horses would be in the autumn when all larvæ are young and the *G. haemorrhoidalis* are still within the stomach and duodenum. The last-mentioned experiments in Table IX show some fumigation results with small Gastrophilus. It will be observed that 1 hour was an amply sufficient time, though a few last-stage larvæ were present as late as September 18. If not caused to detach these would possibly drop during the winter and succumb to low temperatures. In Dallas, Tex., 45 minutes was sufficient to kill young larvæ on December 9, 1916.

The fact that *G. nasalis* attaches in the throat, where the larvæ are not in a position to be affected by the carbon disulphid treatment, emphasizes the fact that "an ounce of prevention is worth a pound of cure."

REPELLENTS.

The rubbing of horses upon posts, bowlders, and other convenient objects suggested a device for use in pasture whereby horses could rub their lips upon a repellent. The short period of effectiveness of repellent substances and the inability to obtain one that will remain on the lips during grazing are difficulties which would seem to be overcome by such a device. A keg reservoir was devised whereby a

flow of repellent, which was regulated by a stopcock, moistened a padded plank by means of a small pipe perforated with holes. This was placed at a salting and resting place of the horses and the amount of rubbing noted was very encouraging. Unfortunately, the horses did not rub the corners of the mouth, which are favorable places of egg deposition, and the scheme was abandoned.

Dr. Van Es suggested the use of a repellent upon the forelegs of horses and other portions of the body accessible to the mouth, so as to cause the common bot fly to deposit eggs upon places where they could not be reached by the horse's mouth. A marked repellent quality was observed in equal parts of pine tar and lard, no adults having been observed to oviposit during the following 4 days. There was apparently no injury to the animal, and 1 part of tar to 2 parts of lard was effective during 3 days. The disadvantage in some of the treatments was the fact that animals would walk through mud and water and cause a decrease in the repellent qualities of the mixture applied. Very good results were obtained with pine tar $3\frac{3}{4}$ ounces, kerosene $1\frac{1}{4}$ ounces, laundry soap 1 ounce, powdered resin 1 ounce, and hot water to make 14 ounces. The pine tar was thinned with kerosene, the soap and resin dissolved in hot water, and the two mixtures poured together. There was not only great repellent action observed, but the resin caused the hair to stick together in small bunches and prevented the adult flies from ovipositing. There was apparently no injury to the skin of the animal, and these same repellents prevented *G. nasalis* from ovipositing under the jaws. A successful repellent that would not require renewal over a reasonable period is desirable, since the loss of time due to the renewal of repellents is a great loss.

MECHANICAL PROTECTIVE DEVICES FOR WORK HORSES.

The protective devices found upon work animals vary, but there are none used in the Dakotas on pastured animals. (See Plate V.) Various forms of fringes are most frequently found and may consist of leather, burlap, or a portion of the leg of trousers. These are probably the least effective of the devices, as examination of teams wearing such fringes developed the fact that they are often found infested with eggs. Leather seems to be the most efficient of the fringes, as it is not so easily blown aside by the wind and does not hinder the horses in breathing. Those extending completely around the head retail for 50 cents each, while those covering only the face sell for 25 cents.

Baskets which are used extensively in nose-fly districts serve as muzzles during the last plowing of corn, but are not very effective nose-fly protectors. The mesh is of sufficient coarseness to permit flies to oviposit if the lips can be touched. They do not always fit well at the top and occasionally a nose fly will get on the inside,

producing great annoyance by its buzzing. During thrashing moisture collects within the basket and, when the dust settles upon this, creates a condition which greatly handicaps the animal's breathing. These baskets retail for 35 cents each when fitted with two snaps.

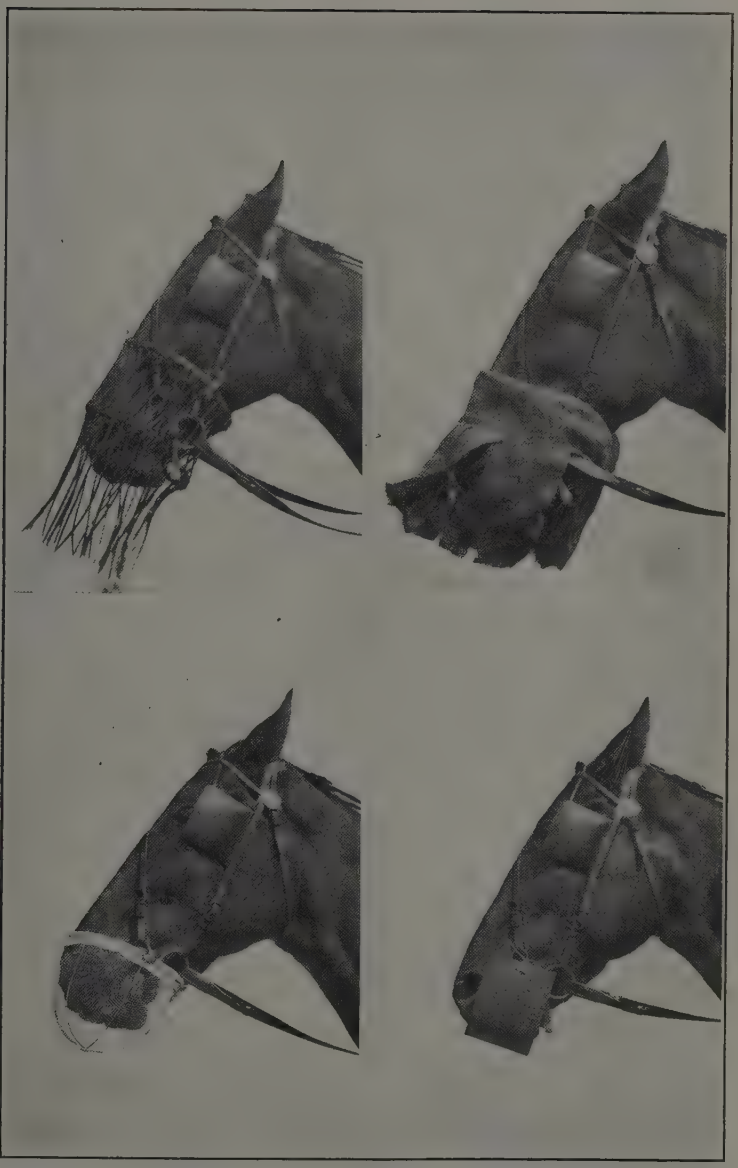
While protection of any description about the lips will prevent many ovipositions and annoyance by flies, by far the most effective device consists of a simple strip of leather extending over the lips and fastened at the bit rings. This actually covers the portions of the lips upon which the flies lay their eggs and upon horses thus protected an absence of eggs and annoyance has been noted. During the movement of the horse's head in walking, especially when working, this protection not only covers the lips, but swings to and fro and tends to repel the flies. The nostrils being exposed, it does not hinder breathing. Due to the cost of leather, very few of these are in use, but if one obtains an old belt from a thrashing machine great numbers can be made. It requires only a strip which will extend from one bit ring to the other and be from 4 to 6 inches in width. The size of the strip will depend upon the size of the horse's head. A snap placed at each end near the center facilitates handling, and the protector can be snapped onto the harness when not in use.

PROTECTORS FOR PASTURED ANIMALS.

Studies of efficiency of halter appliances for pastured horses have been made, and while conclusive results have not been obtained, a type has been designed which promises to meet the demand. At first halters were used with a piece of leather covering the jaws and hanging so as to flap against the lips when the animal walked. The front of the halter was provided with a face net which swung over the nostrils and lips. This proved unsatisfactory, as the flap, if long enough to protect the animals during depositions, was too long during grazing. The horses would step upon them with the fore feet, causing them to break.

A variation from the most efficient work-horse protector was devised by using a piece of duck on the rear, so as to cover the jaws and prevent *G. nasalis* from depositing in this location (see fig. 4). A block of wood under the center and below the lips enables a horse to graze with ease and at the same time be protected from flies when the head is held above the ground. The cloth on the rear also prevents ingress of *G. intestinalis* larvæ by preventing the horse from scratching portions infested with eggs. When the head is placed upon other animals the device occasions such discomfort that almost immediately the horses move and prevent the protected animal from becoming infested from their bodies.

For pasture uses the leather becomes soft and at times exposes the corners of the mouth, but excellent results have been obtained by sub-



DEVICES IN USE TO PROTECT WORK HORSES FROM OVIPOSITING G. HAEMORRHOIDALIS.

Upper left.—A leather fringe is fairly effective. Upper right.—A burlap fringe hinders breathing. Lower left.—A wire basket often permits ovipositions on account of coarse mesh and ill fitting. Moisture and dust collect and hinder breathing. Lower right.—A strip of leather actually covers oviposition places and allows the horse to breathe easily. (Original.)

stituting a hard wood. The weight in either case will compare with the weight of blind bridles. Horses using these in experiments became free of *G. haemorrhoidalis* eggs during the summer of 1916, whereas unprotected animals were heavily infested. There was also a marked difference in the feeding, as protected animals grazed normally in bunches. While the device indicates a favorable preventive measure, before its adoption tests of durability should be made and minor points in the construction determined. It seems possible that the construction could be made so simple that farmers could make the protectors at a nominal price.

A halter attachment would permit horses to graze during times that are favorable for depositions of flies, and would prevent eventual infestations by all three species of Gastrophilus. A shed constructed in the pasture would protect animals from nose flies, although it would not prevent infestations by the other species of Gastrophilus. Such a shed would keep the animals from grazing during times that were favorable for depositions, and could be used for storage of feed during the winter.

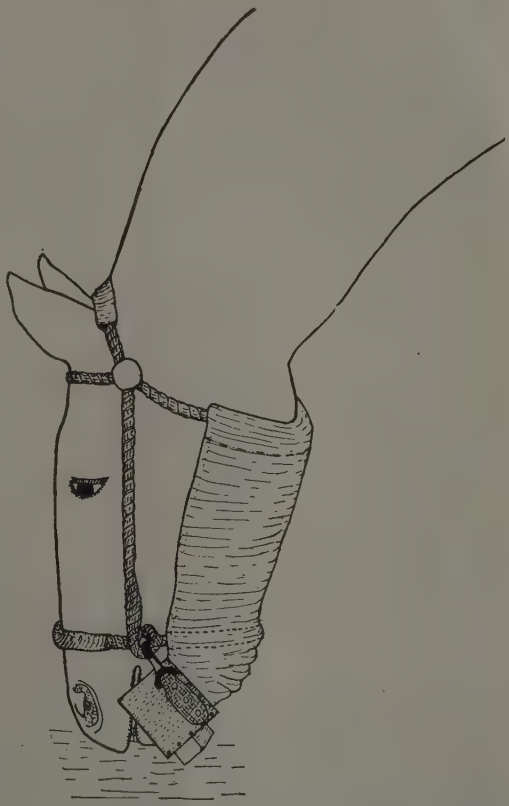


FIG. 4.—A bot preventive. The box prevents "nose flies" from ovipositing when the head is held upright, while the block of wood underneath the box allows the horse to graze easily. The canvas prevents normal ovipositions of the "throat bot-fly," and does not permit the horse to bite the portions infested with eggs of the "common bot-fly." (Original.)

EFFECTIVENESS OF WASHES UPON EGGS.

Regardless of whether horses are treated internally for bots, which is best during the autumn, when larvæ are small, or whether they

wear halter appliances during the summer, it is necessary to treat the eggs during the autumn to prevent a late infestation from the well-incubated eggs after the protectors have been removed. Then, too, the ease with which places so accessible to the horse's mouth can be washed makes the use of washes a practical prevention in regions where bots are not so numerous.

LARVÆ REMOVED FROM EGGS PRIOR TO TREATMENT.

Active larvæ were removed from well-incubated eggs and subjected to substances reported in Table X. Only larvæ in excellent condition were used, and these were observed in watch glasses, small tin boxes, and test tubes at short intervals until dead. When in doubt they were removed with a drop of the liquid to a microscope slide, and the warmth of one's breath was sufficient to cause living ones to move. Larvæ were killed instantly when placed in volatile liquids or gases of carbon disulphid and in absolute alcohol.

TABLE X.—*Resistance of first-stage larvæ of Gastrophilus intestinalis, Aberdeen, S. Dak., 1916.*

Larvæ placed in—	Longevity.	Larvæ placed in—	Longevity.
Dry tin box	72 to 126 hours.	Borax, saturated solution	40 minutes.
Water	76 to 99 hours.	50 per cent alcohol	30 minutes.
Tincture quassia	24 to 36 hours.	Petroleum, refined	30 minutes.
Beta-naphthol in alcohol	20 to 28 hours.	Do	30 minutes.
10 per cent oil of tar emulsion	41 to 48 hours.	Boric acid	13 minutes.
Borax, saturated solution	28 to 41 hours.	33⅓ per cent pine tar and 66⅔ per cent kerosene.	1 minute.
Do	24 to 43 hours.		

Dr. Guyot's results compare favorably with those herein reported. His larvæ remained alive in water for 4 days, nearly a day in olive oil, and more than 14 hours in bichlorid of mercury solution 1 to 1,000.

The movement of freshly emerged larvæ is very rapid upon moist surfaces, but upon a dry surface they seldom move from the original location, although they have been observed to live for 72 to 125 hours. When placed in water the larvæ became submerged with the exception of the posterior spiracles, which remained exposed at the surface. They are capable of living in this manner for 76 to 99 hours.

LARVÆ REMOVED AFTER TREATMENT OF EGGS.

Hundreds of eggs were collected from horses in pastures during the latter part of August and the early half of September. At this time the activities of adults of *G. intestinalis* were being directed to the manes of horses for oviposition, as in most cases the inside of the forelegs and sides immediately behind the forelegs were very grossly infested. These hairs were of sufficient length to render handling easy, and the eggs were about the same age. Except as otherwise in-

dicated in Table XI, infested hair was placed in tubes at air temperatures of a living room and allowed to remain until larvæ were well formed and ready for emergence. Some of the eggs were then tested and the viability determined. A check was not kept, as the brownish color of the dead larvæ easily distinguished them from the transparency of the active larvæ.

TABLE XI.—*Effectiveness of washes upon eggs of Gastrophilus intestinalis, Aberdeen, S. Dak., 1915–16.*

Date eggs treated.	Insecticide.	Exposure.	Number larvæ examined.	Mortality of larvæ.			Remarks.
				Dead.	Living.	Doubtful.	
1915.		*Minutes*					
Sept. 6	Refined petroleum	6–18	7	0	7	0	Engine oil, No. 1.
Do	do	18–31	8	4	4	0	Do.
1916.		*Hours.*					
Sept. 7	Kerosene	24	20	19		1	
Do	1.35 per cent phenols [1]	24	38	38	0	0	Reddish brown in color.
Do	2 per cent nicotine sulphate.	24	17	12	5	0	
Do	Carbolic acid 2 per cent phenol.	24	20	19	1	0	
Do	Lard	24	20	0	20	0	
Do	Nitrobenzine gas	25	38	38	0	0	
Sept. 9	Carbolic acid 2 per cent phenol.	5	28	23	0	0	2 larvæ yellow in color.
Do	Kerosene	29	22	5	17		5 dead larvæ yellow in color.
Do	0.135 per cent phenols [1]	29	23	23	0	0	3 dead larvæ yellow in color.
Sept. 11	Nitrobenzine gas	4	34	7	22	5	
Do	do	10	40	37		3	
Do	do	25	42	42	0	0	
Do	0.054 per cent phenols [1]	26	40	40	0	0	
Do	Kerosene	25	28	5	23		18 larvæ very active.
Do	2 per cent nicotine sulphate.	26	26	9	14	3	
Do	2 per cent carbolic acid	26	38	38	0	0	
Sept 15 [2]	Kerosene	24	55	11	38	6	38 larvæ very active.
Do [1]	Carbolic acid 2 per cent phenol.	24	48	47	0	1	
Do [1]	0.054 per cent phenols [1]	25	49	49	0	0	
Do [1]	Kerosene	147	24	3	19	2	
Do [1]	Carbolic acid 2 per cent phenol.	146	27	27	0	0	
Do [1]	0.054 per cent phenols [1]	147	21	21	0	0	

[1] A proprietary compound of cresol in combination with resin soap.
[2] Eggs not well incubated were treated and larvæ removed Sept. 21.

In the tests with larvæ removed from the eggs it was observed that the minimum period causing death by contact was 1 minute with pine tar 1 part and kerosene 2 parts. The ease with which either of these can be obtained suggested a study of these and similar substances.

It will be observed that kerosene, which is commonly reported to be in use by farmers, even at an exposure of 147 hours, had practically no effect upon larvæ. When eggs upon hair were rubbed they more readily yielded to hatching and apparently the larvæ were more active than from any similar treatment. The kerosene seemed to facilitate the emergence of the larvæ. While it was ineffective against well-developed larvæ, it was thought that upon freshly

deposited eggs it would probably prevent development of the embryo, as is the case with hens' eggs during incubation; but even a test of this kind was only slightly effective.

A 2 per cent nicotine-sulphate solution was only partially effective. Nitrobenzine gas, which has recently been brought to our attention as a fumigant for external parasites of animals by Prof. William Moore, of the University of Minnesota, yielded good results at 25, 24, and 10 hours' exposure, but only a small percentage was killed at 4 hours. The fumigation was conducted in a common glass fruit jar into which a strip of cloth, impregnated with a few drops of nitrobenzine, was suspended.

The phenol compounds, by a contact application, seem to be most effective in destroying young larvæ and preventing the further development of embryos. It will be observed that carbolic acid containing 2 per cent phenol yielded as good results as higher percentages, and that this substance was most effectively used.

With carbolic acid as a wash it will be well to be cautious of its effects upon the hands. If used at too great strength, the exposed skin of the hand will become white and peel off, although it does not affect the skin of the horse, which is protected by the hair.

SUMMARY.

Three species of horse bots—the common bot-fly (*Gastrophilus intestinalis*), the throat bot-fly (*G. nasalis*), and the nose fly (*G. haemorrhoidalis*)—occur in the United States, and each is a source of considerable injury to horses. This injury is produced through worriment caused by the flies at the time the eggs are laid and by the attachment of the larvæ, or bots, in the alimentary tract.

Gastrophilus intestinalis and *G. nasalis* are widely distributed in the United States but *G. haemorrhoidalis* is confined to the North-Central and northern Rocky Mountain States.

The nose fly (*G. haemorrhoidalis*) is by far the most annoying to horses at the time its eggs are laid. The adults appear early in June and reach the maximum of abundance during the first half of the season, disappearing with killing frosts. The eggs are deposited on the minute hairs on the lips, and those near the edges which are kept moist and receive friction hatch in from 5 to 10 days. The larvæ are taken in with food or water and attach themselves to the walls of the stomach. Here they remain until the following winter or spring and then migrate to the rectum, where they reattach. Before leaving the host they usually attach close to the anus and protrude from it. They remain in this position from 40 to 71 hours. After dropping to the ground the bots seek protection and pupate in from 18 to 170 hours later. The pupa stage lasts from 21 to 68 days. The adults are

very active, and as they deposit only one egg at a time they are not so frequently seen about horses as are the adults of the common bot-fly. They take no food in the adult stage. Their length of life is from 1 to 7 days.

The throat bot-fly (*G. nasalis*) deposits its eggs on the hairs under the jaws and to some extent on the shoulders and other parts of the host. The larvæ of this species attach themselves to the walls of the pharynx and also to those of the stomach and duodenum. They do not reattach in the rectum or at the anus as do the bots of the nose fly. Pupation occurs in from 1½ to 2 days after the larvæ have passed from the host, and adults emerge in from 20 to 56 days later. The adults are somewhat longer lived than those of the nose fly. The flies cause considerable annoyance to horses during oviposition but not as serious as in the case of the nose fly.

The common bot-fly (*G. intestinalis*) usually appears later in the season than the nose fly and becomes most abundant just before killing frosts. The eggs are deposited on all parts of the body, but preferably on the fore legs. They hatch upon the application of moisture and friction. From 9 to 11 days after oviposition appears to be the most favorable period for hatching, although some may hatch as early as 7 days and others as late as 96 days after oviposition. The larvæ attach in any part of the stomach, but the last-stage bots are found mostly in the left sac. They continue to drop from the host for a long period of time. Pupation takes place in protected places on the surface of the soil and the pupa stage lasts from 40 to 60 days.

All Gastrophilus larvæ are surprisingly resistant to chemicals. The treatment of horses with carbon disulphid in three doses followed by a physic is satisfactory if administered in the late fall. Spring treatment is less effective, as the full-grown larvæ are more resistant, and many of the nose-fly bots have left the stomach and passed back to the rectum at that time.

Larvæ of *G. haemorrhoidalis* may be removed from the rectum mechanically, but this is laborious. The use of enemas containing insecticides is ineffective.

As a repellent, pine tar mixed with other material gave good results against the common bot-fly and the throat bot-fly. Such mixtures may be utilized to cause the flies to lay eggs on parts of the body less accessible to the horse's mouth.

Various nose protectors are in use against *G. haemorrhoidalis*, but there are objections to many of them. A piece of leather suspended below the lips from the bit rings is simplest and best. For animals on pasture a halter with a box-like arrangement and throat cover has been devised to protect horses against infestation by all three species.

Kerosene oil used as a wash is ineffective in destroying the eggs of Gastrophilus, but certain other substances have given good results. Carbolic acid containing 2 per cent phenols is satisfactory for destroying eggs when applied to the infested parts of the host.

BIBLIOGRAPHY.

ALDRICH, J. M. A Catalogue of North American Diptera. 680 pp. Washington, D. C. 1905. (Smithsn. Misc. Coll., vol. 46, No. 1444.) Pp. 413–415, *Gastrophilus*.

ANONYMOUS. Bots harmful to the horse. *In* U. S. Dept. Agr. Weekly News Letter, vol. 1, No. 5, p. 4, Sept. 10, 1913.

ANONYMOUS. Bots of horses. *In* Agr. Gaz. N. S. Wales, vol. 20, pt. 3, pp. 203–208, 6 figs., Mar. 2, 1909.

BRAUER, FREDRICH. Monographie der Oestriden. 291 pp. Wein, 1863.

BUFFINGTON, G. L. *Gastrophilus haemorrhoidalis* in the pharynx of a horse. *In* Amer. Vet. Rev., vol. 29, No. 1, pp. 37–38, 1905.

CARPENTER, G. H., and HEWITT, T. R. Some new observations on the life history of warble flies. *In* Irish Naturalist, Dublin, vol. 23, No. 10, pp. 214–221, Oct., 1914.

CLARK, BRACY. Observations on the genus Oestrus. *In* Trans. Linn. Soc. London, vol. 3, pp. 289–329, col. pl. 23, 1797.

CLARK, BRACY. An Essay on the Bots of Horses and other Animals. 94 pp., 2 pl. London, 1815.

CLARK, BRACY. Of the insect called Oistros by the ancients and of the true species intended by them under this appellation. . . . *In* Trans. Linn. Soc. London, vol. 15, pt. 2, pp. 402–410, 1827.

COLLINGE, W. E. Some observations on the eggs of the horse bot fly *Gastrophilus equi* (Fabr.). *In* Jour. Econ. Biol. vol. 5, No. 1, pp. 9–17, 1 fig., March 31, 1910.

DUGGAR, B. M. Notes on the maximum thermal death-point of *Sporotrichum globuliferum*. In Bot. Gaz., vol. 27, No. 4, pp. 131–136, Feb., 1899.

FRENCH, C. The horse bot-fly. *In* Jour. Dept. Agr. Victoria, vol. 1, pt. 7, pp. 693–696, July, 1902. Page 697—Treatment for the bot fly, by J. R. Weir.

FROGGATT, W. W. The bot-fly (*Gastrophilus equi*). *In* Agr. Gaz. N. S. Wales, vol. 19, pt. 3, pp. 229–233, pl., Mar., 1908.

GARMAN, H. The bot-flies of the horse (*Gastrophilus equi* and *G. nasalis*). *In* Kentucky Agr. Exp. Sta. Rept. 7, 1894, pp. XXVII–XXXIV and Rept. 8, 1895, pp. XLIX–L. The throat bot-fly of the horse (*G. nasalis*).

GUYOT, J. Contribution à l étude des larves de gastrophiles (Oestrides) parasites de l'estomac du cheval. *In* Arch. Par., vol. 4, pp. 169–221, 11 figs., 1901.

HUTCHEON, D. Bots or "Paapjes." *In* Agr. Jour. Union South Africa, vol. 8, No. 2, pp. 194–200, Aug., 1914.

KRÖNING, —. Die Gastruslarvenkrankheit der Pferde in ihrer Bedeutung für die Fohlenaufzucht besonders veredelter Zuchten. *In* Ztschr. Veterinärk., Jahrg. 18, Hft. 5, pp. 201–211, May, 1906.

LAHILLE, F. Los gastróphilos en la República Argentina. *In* Bol. Min. Agr. Argentine Republic, vol. 13, num. 12, pp. 836–856, 8 fig., col. pl., Dec., 1911.

LOCHHEAD, W. Some notes regarding nose and other bot flies. *In* Forty-sixth Ann. Rept. Ontario Ent. Soc., 1915, pp. 102–108, 1916.

LUGGER, OTTO. Insects injurious in 1896. *In* Second Ann. Rept. Agr. Exp. Sta. Univ. Minn., 1896, pp. 31–257, fig. 2–187, 16 pl., 1897. Pages 235–245. B. Bot-flies, Gad-flies (Oestridæ).

MACDOUGALL, R. S. Insect pests of domesticated animals. *In* Trans. Highland and Agr. Soc. Scot., ser. 2, vol. 5, pp. 187–190, 1899.

MACLEAY, W. S. On the insect called Oistros by the ancient Greeks and Asilus by the Romans. *In* Trans. Linn. Soc. London, vol. 14, pp. 353–359, 1824.

MICHENER, C. B. Diseases of the digestive organs. *In* U. S. Dept. Agr. Bur. An Indus. Spec. Rept. on Diseases of the Horse, 1911, pp. 34–74, 3 pl. Page 61, pl. II. Bot-fly larvæ.

MOORE, WILLIAM. Fumigation of animals to destroy their external parasites. *In* Jour. Econ. Ent., vol. 9, No. 1, pp. 71–80, fig. 5–6, Feb., 1916.

NILES, E. P. Animal parasites III. Virginia Agr. Exp. Sta. Bul. 110, pp. 27–37, fig. III–VIII, March, 1900.

ORMEROD, ELEANOR A. Report of observations of injurious insects. . . . 14th, 1890. 144 pp. London, 1891. Pages 64–71, Horse bot fly; horse bee, *Gastrophilus equi* Fab.

OSBORN, HERBERT. Insects affecting domestic animals. . . . U. S. Dept. Agr. Div. Ent. Bul. 5, new ser. 302 pp., 170 figs., Washington, D. C., 1896. Pages 72–114, Family Oestridæ. (Bot-flies, breeze flies.) Pages 76–84, fig. 37, pl. 2, The horse bot-fly. (*Gastrophilus equi* Fab.)

PARKER, R. R. Notes concerning *Gastrophilus haemorrhoidalis* Linnaeus (Dipt.). *In* Jour. N. Y. Ent. Soc., vol. 24, No. 4, pp. 253–255, figs. 1–2, Dec., 1916.

PERRONCITO, E., and BOSSO, G. Sul Metodo di Distruzione delle Larvæ d'Estro, *Gastrophilus equi*, nel Ventricolo del Cavallo. 31 pp. Torino, 1897. Traduction francaise, Bulletin veterinaire No. 67, 1900, pp. 569–590.

PERRONCITO, E. Importanza patologica delle larve d'estro nello stomaco del cavallo. *In* Gior. Reale Soc. ed. Accad. Vet. Ital., vol. 51, No. 32, pp. 801–805, Agosto 9, 1902.

SEYDERHELM, K. R., and SEYDERHELM, R. Die Ursache der perniziösen Anämie der Pferde. *In* Archiv für Experimentale Pathologie u. Pharmakologie, Bd. 76, Hft. 3 u. 4, pp. 149–201, May, 1914.

SWENK, M. H. The bot-flies affecting live stock in Nebraska. *In* Ann. Rept. Neb. St. Bd. Agr. for 1908, pp. 327–341, figs. 25–32.

TOWNSEND, C. H. T. On the so-called throat bot. *In* Ent. News, vol. 3, No. 9, p. 227. Nov., 1892.

VELU, H. Note sur une lesion de myase intestinale chez le cheval. *In* Recueil Med. Vet. Affort, vol. 92, No. 13, pp. 408–410, 1916. (Rev. App. Ent., ser. B, vol. 4, No. 10, p. 164, Oct., 1916.)

VERRILL, A. E. The external and internal parasites of man and domestic animals. . . . Hartford, Conn. [1870]. 140 pp. (From Fourth Ann. Rept. Sec. Conn. Bd. Agr., 1869–70.)

WARBURTON, CECIL. Annual Report for 1899 of the zoologist. *In* Jour. Roy. Agr. Soc. England, ser. 3, vol. 10, pt. 4, pp. 667–678, 1899. Pages 668–669, Horse bot-flies.

WESSEL-WILSTER, W. Abtreibung von Gastru larven bei Fohlen durch Schwefelkohlenstoff. *In* Berliner Thierärztliche Wochenschr., Jahrg. 1901, No. 9, p. 156.

WILLISTON, SAMUEL W. Manual of North American Diptera, ed. 3. 405 pp. New Haven, 1908.

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Notes on the Preoviposition Period of the House Fly. (Department Bulletin 345.) 1916. Price, 5 cents.
Experiments During 1915 in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 408.) Price, 5 cents.
Ox Warble. (Entomology Circular 25.) 1897. Price, 5 cents.
Horn Fly. (Entomology Circular 115.) 1910. Price, 5 cents.
The Fowl Tick. (Entomology Circular 170.) 1913. Price, 5 cents.
Insects Affecting Domestic Animals. (Entomology Bulletin 5, n. s.) 1896. Price, 20 cents.
Notes on Mosquitoes of the United States. (Entomology Bulletin 25, n. s.) 1900. Price, 10 cents.
Notes on "Punkies." (Entomology Bulletin 64, Pt. III.) 1907. Price, 5 cents.
Information Concerning the North American Fever Tick, with Notes on Other Species. (Entomology Bulletin 72.) 1907. Price, 15 cents.
Economic Loss to the People of the United States through Insects that Carry Disease. (Entomology Bulletin 78.) 1909. Price, 10 cents.
Preventive and Remedial Work Against Mosquitoes. (Entomology Bulletin 88.) 1910. Price, 15 cents.
The Rocky Mountain Spotted-Fever Tick, with Special Reference to the Problem of Its Control in the Bitter Root Valley in Montana. (Entomology Bulletin 105.) 1911. Price, 10 cents.
The Life History and Bionomics of Some North American Ticks. (Entomology Bulletin 106.) 1912. Price, 30 cents.

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